THE JOURNAL OF GAS LIGHTING
WATER SUPPLY & SANITARY IMPROVEMENT

VOL. CXI. No. 2469.] LONDON, SEPTEMBER 6, 1910. [62ND YEAR. PRICE 6d.

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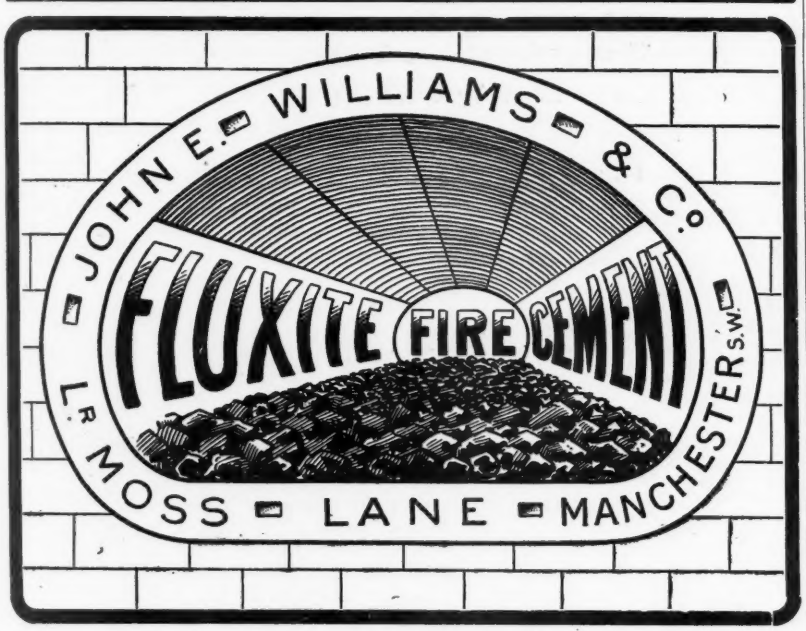

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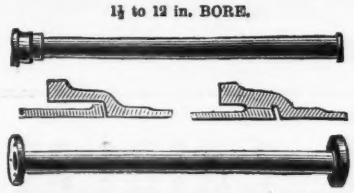

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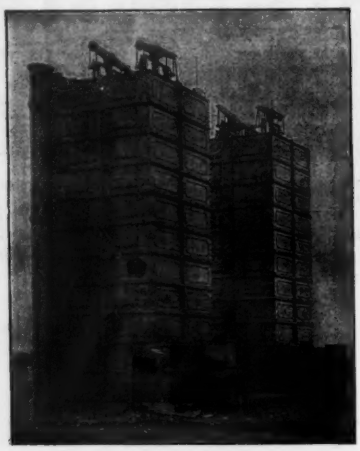

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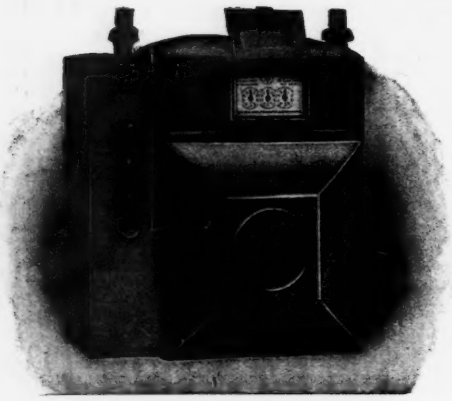

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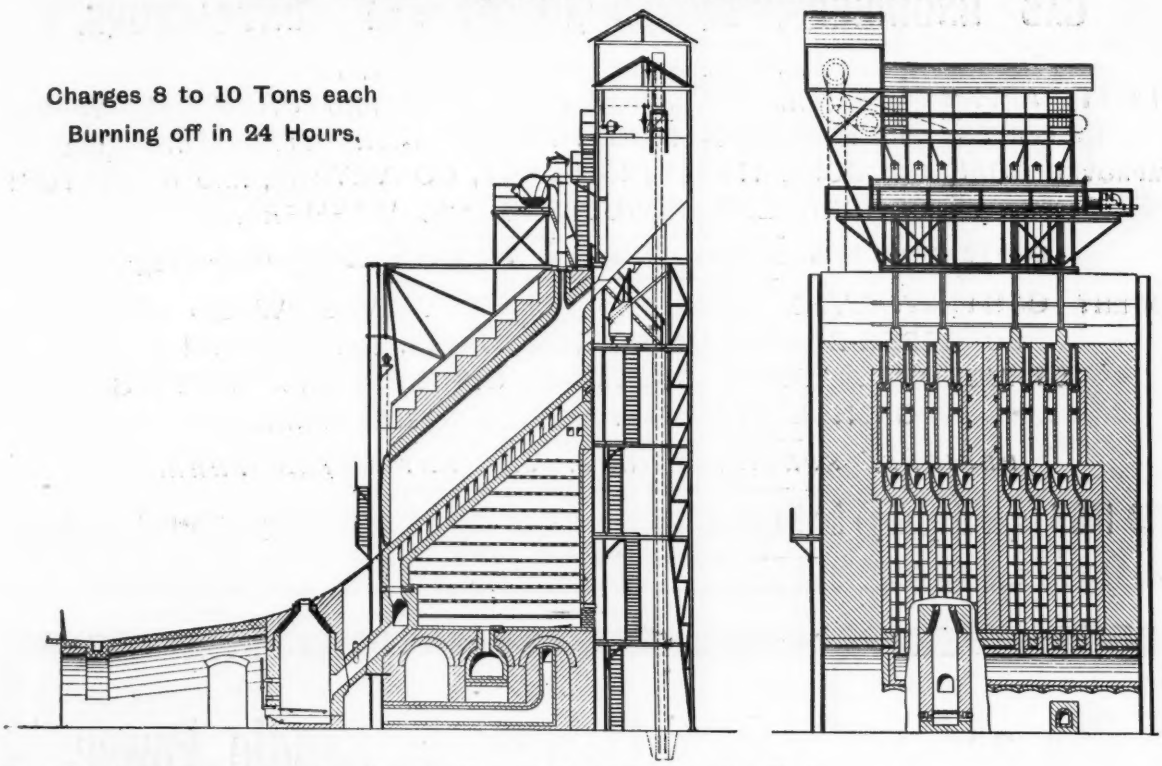

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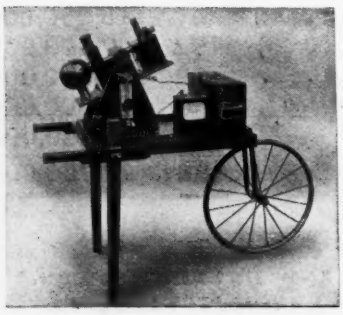

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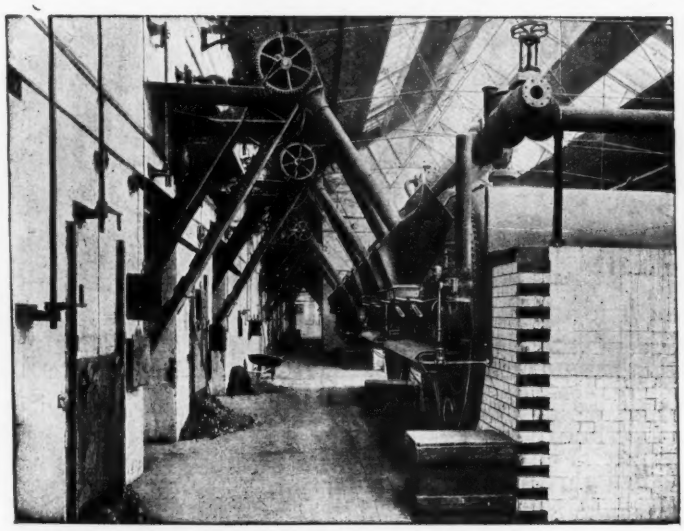

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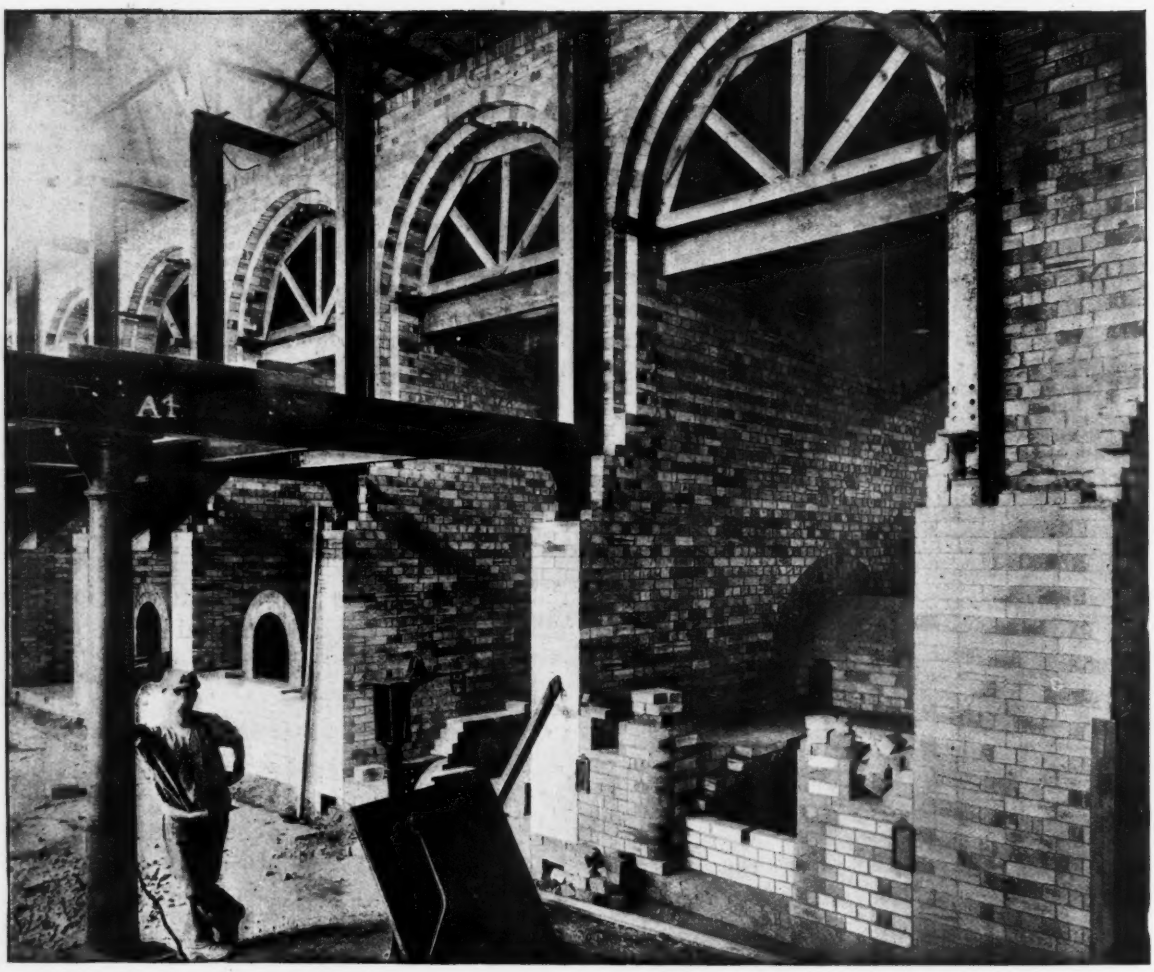

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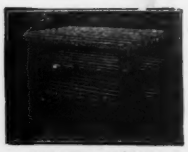

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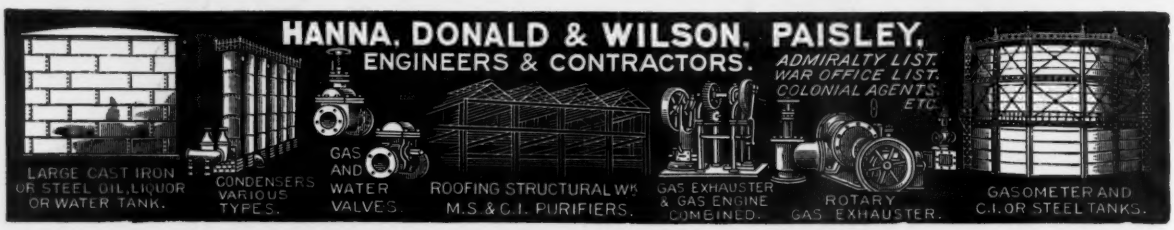
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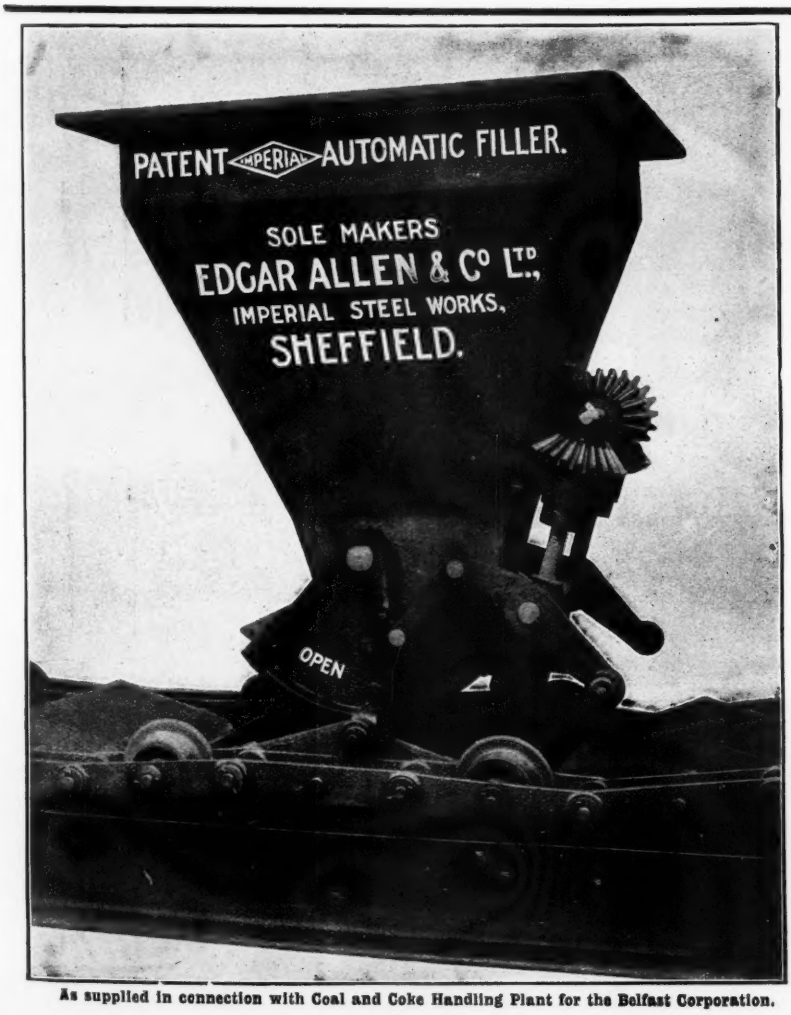

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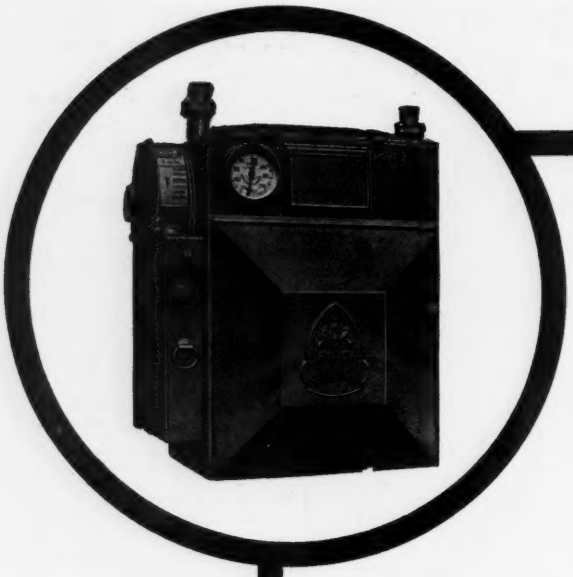

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EDITORIAL NOTES—GAS, &c.

Greater Protection and Latitude for the Industry.

MATTERS of current interest have postponed until now a review of the salient features of the parliamentary session's work in connection with the gas industry—work that is yet uncompleted pending the confirmation by the House of Commons of the jointly promoted Standard Burner Bills, which have had such a triumphant march through both Houses to the point at which they now stand, despite an opposition that has stopped short at nothing—not even at insinuation of what is tantamount to robbery and jobbery—to secure their overthrow. However, every session now solidifies the position of the gas industry in the matter of legislation which helps to shape its conditions to fulfil its obvious destiny. This session has been no exception to the rule; and if the Standard Burner Bills receive the Royal Assent before the close of the year (upon which event there is not the slightest misgiving on our part), the session will stand out with unusual prominence among those in which work has been accomplished conducive to the forwarding of the material interests of the industry. Parliament to-day prescribes, with the greatest freedom, 14-candle gas tested by the "Metropolitan" No. 2 burner. It has given Middlesbrough this year, as it gave Bury last year, the right to a standard of 12-candle power. These are local authority gas supplies; and there is parliamentary recognition in this and other ways that illuminating power *per se* is a moribund quality on which to found a standard. The time, we opine, is not far distant when Parliament will treat with favour suggestions for the complete supersession of that standard by a calorific power one. But again this session, in the cases of Farnham and the Standard Burner Bills, Parliament has shown that it will not impose a dual test upon the industry. Local authorities interested as competitors would manacle gas companies in this manner if they had their will; and cheap gas service to their communities could go to the wall for aught they care. Fortunately, Parliament will have none of it. It stands determinedly between local authority selfishness and the public interests; and there is something to be thankful for in the evidences of this that have been presented during late sessions. A case in point was the effort of the Brighton Corporation to impose restrictions upon the Gas Company in respect of the use of carburetted water gas. At the instance of the Corporation, Dr. Haldane (who was a member of the Home Office Committee that reported in favour of restriction twelve years ago) was called; and, while he claimed a moral effect from that report, he recognized a prudent consideration by gas suppliers of their obligations to the public, and changed circumstances which, in his view, made restriction a matter of less importance than formerly. His blessing was not in the form expected by the Corporation; and Parliament did not concede what the Corporation wanted.

But, on the other hand, Parliament does see that local authorities—always ready enough to impose restriction upon, and obstruct with conditions, their competitors—themselves are not immaculate, and not without need for restriction and stronger conditions in their trading. Unfortunately, however, there are no bodies in existence, other than Parliament, that can, without considerable private expense and trouble, make any very effective effort in putting upon them statutory restraint, unless extra-territorial authorities, within whose district the trading is carried on, oppose them. Parliament has also recognized this; and Parliament is acting accordingly. And not before it is time. Last session this was shown in the limitations imposed upon gas profit appropriation; and this session there has been a further step in a deliberate refusal to allow the Corporation of Glasgow to use profits made by the gas undertaking for the relief of the rates. Whatever profits are made, after all financial obligations are discharged, are to be devoted to the improvement of the service of the undertaking to the community. But the Gas Department are to have the liberty of making differential charges for gas for different purposes, as is necessary under the competitive circumstances of the time. The Commission under the Private Legislation Procedure (Scotland) Act, who considered the Kirkcaldy Order, also declined to allow a provision to stand relating to the appropriation of the surplus gas profits to the burgh general assessment. Again this session, in the interests of the liberty and protection of the gas industry, there have been several additions, in Bills and Orders, to the Heywood and Mountain Ash stand-by clause precedents. The Home Office and the Local Government Board seem, however, to have a preference for the Mountain Ash model, which only gives protection to town gas supply against private gas plants; while the Heywood precedent gives protection likewise against electricity. In the Rhondda Bill, the promoters gave up electricity in deference to the views of the Local Government Board; but, in favour of the Warrington Gas Department, Parliament has allowed electricity to stand in conjunction with private gas plants. We fail to see the slightest reason why any distinction should be made between electricity and private gas plants, when a town-gas supply is put in merely as a protection against a business competitor; for the capital expended in making the provision, and the work entailed in meter inspection and so forth, are the same whether business results or not.

Another direction in which Parliament has made recognition of the necessity for some increased power on the part of gas companies has been in creating fresh precedents for the redemption of obsolete and unproductive capital. Eleven years ago, Sir James Rankin's Committee recommended that efforts should be made by companies having obsolete capital to wipe it out by means of a sinking fund, or otherwise. But, until this session, only the Gaslight and Coke Company had taken the power for redeeming capital (up to a million pounds) by half-yearly appropriations from revenue. Now the Brighton Gas Company have secured the right to extinguish £57,000 of capital (unrepresented through works abandonment) by half-yearly appropriations of £1800 from revenue. This is not what the Company asked for in their Bill; but it answers the requirements. In the case of the Company that is to be brought into being under the title of the Bishop's Stortford, Harlow, and Epping Gas and Electricity Company, by the amalgamation of a number of comparatively small Essex concerns, a redemption fund has also been allowed, up to a certain defined limit. But this is a matter that can be gone into in greater detail when the Acts themselves, with the exact clauses, are under review.

We will not, in this glance at the session's work, enter into the question of the Standard Burner Bills, and of the persistent efforts made to destroy them at every point of their advance. It has, however, been a pleasure to know that the support given to the Bills, by special articles in these columns in February and March last, and the comments upon the proceedings and upon the singularly vexatious and vindictive antagonism to the measures, have been in complete accord with the whole technical view of the gas industry—with isolated exceptions. The decisions of the Lords and Commons Committees, unqualified as they were, crowned all the effort that has been put forward on behalf of the Bills and of the progress of the industry. The Committees saw clearly through the obfuscating veil that the opposition tried to draw over the real ends of justice and progress that the Bills are destined to serve. The measures alone have made the session of historic interest for the gas industry; and all who have taken part in their promotion, and have worked for their success, have the knowledge of having been engaged in an excellent cause.

At one time there was reason to complain of the attitude Parliament was taking in connection with the industry; but now there is much indication of a more open appreciation on the part of Parliament (for which, more than to any other man, we are indebted to the late Sir George Livesey) of

the facts that the industry has been, and is, passing through a transition period, and that greater liberty and greater protection of the interests of the industry are the most certain means to the best service to the community, and that surely is what all domestic legislation of the kind should be designed to promote. The prediction of Sir Henry Kimber, the Chairman of the Commons Committee, who considered the Standard Burner Bills—that the session's work has carried us far on the road to a revision of the general legislation affecting the gas industry—is no doubt quite true. We hope it has, providing that, before legislation, there is full and impartial inquiry into the position of the industry in respect of the lines of its development, and the ends it has to serve, and in respect, too, of the injury inflicted by the actions and tactics of supervising local authorities who are also business competitors. The gas industry is now in the mood, and it has the men and the material, to seriously enter upon a discussion, before a thoroughly impartial and intelligent tribunal, of the lines of revision of its general legislation. The sooner that such discussion comes now, the better in our opinion.

A False Foundation.

Our electrical friends are not conducting their defence of the loss of the Westminster lighting contract in anything like a courageous or fair manner. Nothing more dishonourable than the calculations made by them, and published in the Daily Press, to show that the Gaslight and Coke Company have undertaken this lighting at a concrete loss, has ever been seen in the controversies of the two industries. If the calculations are not dishonourable, then they have been made in absolute ignorance of the true facts of the case in relation to the type of lamp that is going to be employed in the lighting of the considerable part of Westminster that is covered by the contract. Yet we cannot bring ourselves to think that men of the position of Mr. E. Willmot Seale, the Secretary of the Charing Cross (West-end and City) Electric Supply Company, Limited, and the Editor of the "Electrician" can claim that (though they may simulate) they have no knowledge of the efficiencies of the new high-pressure type of inverted lamp such as will be employed. If they have not this knowledge, then most willingly we withdraw the term "dishonourable," and substitute the words inexcusable ignorance. But, for either the one or the other, both Mr. Seale and the "Electrician" ought, at this time of day, to be thoroughly ashamed. A letter by Mr. Seale that has had widespread publication was inserted in the "Journal" last week; and, as an addendum to it, there appeared an explanation as to how he arrived at the figure of 10½d. per 1000 cubic feet as the one that the Gaslight and Coke Company must be charging for the gas to be consumed under this lighting contract. In a previous issue (as mentioned in the "Electric Supply Memoranda" last week), the Editor of the electrical paper already named, by some subtle process of computation, found that the Company were only charging 5½d. per 1000 cubic feet!

However, what both Mr. Seale and the Editor of the "Electrician" have done is to take an altogether wrong basis for their calculations; and we cannot, with all the publication that has been made, conclude that this has not been done designedly. They have referred to a report by Mr. W. H. Bradley, City Engineer of Westminster, in which he gives the consumption of a nominal 1000-candle power high-pressure lamp as 30 cubic feet. But the lamp he was alluding to, as we have before pointed out for the edification of our grievously misinformed or dishonest electrical friends, is of the old type, and is not the new form of inverted high-pressure lamp. The old type of vertical burner lamp only had an efficiency of about 30 candles per cubic foot of gas consumed; while the new type lamp (such as is to be fitted in Westminster) has an efficiency of 60 candles per cubic foot. The result of taking the old basis and old type of lamp is that Mr. Seale finds that a 3000-candle power lamp would consume 90 cubic feet of gas per hour, or, on a lighting scale of 3940 hours per annum, a total consumption of 354,600 cubic feet. Now, as a matter of fact, the 3000-candle power high-pressure inverted lamps such as are to be used in Westminster, will each only consume 50 cubic feet of gas per hour; so each lamp will only demand 197,000 cubic feet of gas in the 3940 hours, and not 354,600 cubic feet as stated by Mr. Seale—a difference of 157,600 cubic feet of gas! It is to be hoped that those who have been responsible for this attempt to mislead the public by a distortion of facts will do their best to make amends by rectifying their figures with equal prominence.

Then, by a very crude process of calculation, Mr. Seale arrives at the astonishing statement that the cost of gas manufactured by the Gaslight and Coke Company is 1s. 8½d. per 1000 cubic feet, and the cost per 1000 cubic feet of gas sold is 1s. 10d. Therefore, by his processes of reckoning and reasoning, we may take it that the Company are losing 11½d. per 1000 cubic feet on all the gas that will be consumed for high-pressure lighting under the Westminster contract. The calculations are interesting as testifying to the length in absurdity to which the uninitiated in gas statistics can go. We should advise Mr. Seale to study carefully the standard work known as "Field's Gas Analysis;" and therein he will find the truth of the matter. The last issue is for the entire year 1909. In that year, the net cost of coal used, less residuals, per 1000 cubic feet of gas sold, amounted to 5·54d.; and the other manufacturing charges (including 3·87d. for wear and tear), came to 6·34d. Therefore (including the 3·87d. for wear and tear) the net cost of gas into the holders is only 11·88d. per 1000 cubic feet sold. It is absurd, in connection with public lighting, to take into account the average distribution charges as shown by the accounts, amounting to 5·24d. per 1000 cubic feet sold, as this is almost completely made up of the expense incurred in the private supply of gas, embracing service, meter, and stove repairs, and wear and tear; and in his calculations Mr. Seale fails to deduct from these expenses, the rental received from the ordinary and prepayment consumers. He had better sit down quietly, and revise his calculations, and give the public the benefit of them. It is a pity he rushed into print in the rash manner that he did, and presented to the public such indefensible foundations for his contentions.

There is one other matter to which Mr. Seale incidentally alludes, and that is the capital expenditure involved in providing the small diameter steel mains that are being laid in connection with this high-pressure distribution. High-pressure public lighting is only a means to an end. High-pressure gas supply is a development of the ordinary business of a gas undertaking; and it is the intention that these high-pressure mains shall have other profit-producing tributaries besides the public lighting. The London Electric Supply Companies cannot plead ignorance as to what is being done in the neighbourhood of Fleet Street in the matter of private business in high-pressure gas supply; nor of what is being done from local gas-compressing stations in the way of parade lighting. One of the very first changes that will take place in connection with the high-pressure gas system in the West-end (we know this on good authority) will be to take out the special compressing plant at the Victoria Station of the London, Brighton, and South Coast Railway, and draw a supply direct from the new general high-pressure system. The high-pressure system is the means by which gas undertakings can, and will, compete with electric flame arc lighting; and all the sophistry, misapprehension, dishonesty, or whatever is the right epithet to apply to certain statements and calculations contained in the epistolary efforts of our electrical competitors, will not stay the proper development of gas supply on the lines necessary to maintain a superior position in the competition of the times. The gas industry is not yet bereft of business acumen, as the electrical industry knows to its cost; and there is no hesitation in the gas industry to spend capital in order to follow the natural lines of expanding business capacity. Mr. Seale, of course, never heard of electrical undertakings that have considerable lengths of cables—laid at enormous expense—to which there are few connections other than a modest number of street-lamps.

The Value of Conference—Security in Enterprise.

This is the month of many congresses and conferences; and above them all stands the meeting of the British Association for the Advancement of Science. There are many who are sceptical as to the value of this annual fixture. We are not with them. It must necessarily be, where the subject-matter that engages attention is so varied, that much of the torrential rhetoric that we have annually at this meeting will not appeal to every individual. But the mere fact that the meeting does not minister to our individual fancies, inclinations, or mental pursuits, is not a sufficient reason for an unqualified, general condemnation. The Association has provided a platform for our philosophers, for the classical work of the giants in science, in a manner that no other

organization has done. It is an institution that has a link, too, with the popular mind; and the annual proceedings course through channels that are not open to the ordinary scientific society. It is, consequently, impossible to tell the value of such an organization as an instigator of good; we cannot tell what a force it is in the stimulation it gives, individually and collectively, in scientific and human affairs. In some of the papers we may trace the hand of the visionary, or the man with a crank; and much that is in them may be worthless, and instantly pass away into oblivion. But in the President's Address, and in those of the Chairmen of the sections, we have the luminous views of men of the first order in their respective departments of scientific, technical, social, economic, or other work. Although high in rank, their views are not necessarily to be accepted as conclusive, or as the last word. Such men as these, however, are not usually blind zealots; they are themselves searchers after the truth. And their aim is to set before their hearers and their peers the position of things as they see and find them. Professor Bonney, the President for this year, treated in his address of a subject that he has made much his own, but which does not possess any direct interest for pages devoted to an industry such as that of gas. He refrained in his address from drawing any definite conclusion from certain hypotheses that he presented; and in calling attention to the omission, he made remarks which presents to us one direction in which presidents and contributors to the proceedings of scientific and other bodies are in the position to do most valuable work without submitting arbitrary conclusions from something as yet unproved. "There are," he said, "stages "in the development of a scientific idea when the best ser- "vice we can do it is by attempting to separate facts from "fancies, and by remembering that if hypotheses yet on "their trial are treated as axioms, the result will often bring "disaster, like building a tower on a foundation of sand." There is a lamentable accumulation of verification of the truth contained in the latter words. Our scientific and other organizations have before them infinite work, progress in which means the greater prosperity of industries, and through industries of the peoples of the world.

An association covering such diverse fields of thought and research has the effect of providing, as it were, intercommunication between those fields. Much in one region of scientific, technical, or economic work may be discovered that would be of considerable value to the workers in quite another region; but its good in the latter may be lost through sheer ignorance as to what has been transpiring elsewhere. In industry fresh discovery has often had the limited application provided by the industry of its birth; while had the workers in other industries been aware of it, beneficial application might possibly have been considerably extended. The British Association does not eliminate, by its work, the danger of this curtailment of the fruitful application of discovery; but it has effect in this direction by the distribution of information and the stimulation that it exerts through the intercourse it provides. If we descend from the scientific and technical to the economic for illustration of the advantage of this general intercourse, much suggestive thought for the administrators of all industries whatever their kind may be found in the address of Sir A. Llewellyn Smith to the Economic and Statistic Section of the Association. He dealt with some of the causes of unemployment, examination of which led him to the favourable contemplation of that polemical subject of a national contributory scheme of insurance against unemployment—a scheme to be universal in its operation within the limits of a large group of trades. This was the main theme of the address. But we pass it by here, and just quote from it two axiomatical phrases that can be applied to all industries, and not least to that of gas manufacture and supply. "One significant economic tendency of the present day is "the growing recognition of the importance of security and "regularity in all operations of industry and commerce." That is one; another is: "Security is an essential condition "of all industrial and commercial development." There are maxims in these two sentences that should be posted up in the administrative rooms of every industrial enterprise, and not by any means least in those of every gas undertaking in the country. With them before administrators, it would be but natural to apply the question to every line of activity of the enterprise, In what way will security in it be best promoted? There we have a fundamental thought for all technical and commercial enterprise, and upon it one could dilate to any extent. It would, however, all work out to the one conclusion, that security is best served by the most broad-minded and liberal policy, in regard to both the undertaking's local activities and those which are collectively undertaken for the good of the industry at large. In relation to the plans for the protection and commercial expansion of the gas industry that are currently occupying consideration, let each one remember that "Security is an "essential condition of all industrial and commercial expan- "sion." If these words could be driven home, there would be no doubt as to co-operation—such as was outlined recently in Mr. J. W. Helps's Presidential Address to the Institution of Gas Engineers—becoming one of the dominating factors in our industrial welfare and development.

Various subjects of specific interest to our readers have been dealt with during the meeting of the Association; but reference to them may be postponed. One of them is a report—reproduced this week—by Professor W. A. Bone, in which he gives a valuable digest of the results of the principal researches upon the chemical aspects of gaseous combustion during the past thirty years. In the final part of the report, he treats of the influence of hot surfaces upon combustion, which, it will be remembered, was the cardinal feature to gas engineers and chemists of his lecture to the Institution of Gas Engineers in 1908.

Standardization of Gas Supply.

A FAVOURABLE and sympathetic article by an "Engineering "Correspondent" (signing himself "A.C."), on "Stan- "dardization of Gas Supply," has appeared in the "Illumi- "nating Engineer." It outlined in a very fair manner (though here and there a little looseness is perceptible), the events and progress of the gas industry in the manufacture and the utilization of the primary product, that have led up to the claim, while illuminating power is the standard of quality, for a universally applicable standard test-burner such as we have in the "Metropolitan" No. 2. It is freely acknowledged that this burner is a great improvement on its predecessor; and the reason for this view is that it will bring about uniformity in the method of testing gas. "This "is of the greatest possible importance to the industry, to "the consumer, and to the manufacturers of gas plant; for "the adoption of this burner 'of a certain, definite' [*sic*] "consumption, will convey to the simplest mind a clear "understanding as to what the value of the gas is, and will "give to the manufacturers of gas plant the power to "standardize their apparatus, with resultant economies in "the cost of production." This requires qualification. The No. 2 burner is the best for the purposes of the industry and of the consumers, so long as Parliament adheres to illuminating power as the standard of quality. But in view of the present uses of gas, it does not denote what is the real value of gas to the consumers. We shall have to wait for the calorific power standard for that. But may we make a suggestion to the "Illuminating Engineer"? It looks, we believe, upon this proposal as a "rational" one; and its own policy in matters appertaining to illuminating agents is one of impartiality. This being so, our monthly contemporary can do a service by taking part in impressing upon those misguided local authorities who are owners of electricity supply concerns, but not of gas undertakings, and who have shown a readiness to oppose that which stands for progress in gas supply, that they are not doing the best for their communities by opposing the "rational proposals" of their competitors, more especially seeing that local authorities with gas-works (including such an important Corporation as that of Manchester) have been among the first to adopt these "rational proposals." The opposition of those interested in putting obstacles in the way of the progress of private enterprise in gas supply causes endless and unnecessary expense, which falls upon the consumers of gas, who are the constituents of the local authorities. There is one correction that should be made in the article of "A. C." It is that the three Standard Burner Bills were promoted not by only eight Companies, but by a number representing nearly fifty gas-supply areas.

An Appeal to the Juniors.

As the holidays, especially for people residing north of the Tweed, are now practically over, officials of Associations are beginning to prepare for the work of the approaching session; and one of the first to show signs of activity is Mr. W. Geddes,

Hon. Secretary and Treasurer of the Eastern District Division of the Scottish Junior Gas Association, who has sent us his syllabus for 1910-11, which will be found in another part of the "JOURNAL." Useful as the Association has proved to be, the Council consider that it might be rendered much more so by an increase in the membership; and with this end in view Mr. Geddes has sent to a number of managers who are not at present upon the roll, but whose works are within the area covered by the Association, a letter setting forth its aims and objects, accompanied by an earnest appeal to them to assist it by becoming members themselves and by bringing it to the notice of those under their charge. The objects of the Association are fully stated in the letter. It is pointed out that before the formation of the Association in 1904, there was no organization in Scotland to which those occupying junior positions in the gas industry were admitted, and in which their interests were specially provided for. This want the Association supplied, without in any way superseding or supplanting the Senior Associations. Since its inception, the members have had before them papers from their own number which have given rise to useful discussions, and lectures from gentlemen eminent in the gas profession. Moreover, visits have been paid to gas-works, collieries, oil-works, meter-works, fire-brick works, &c.; thus increasing the practical knowledge of the members, who also have at their command a library consisting of about thirty standard works. The value of such an organization to juniors does not need emphasizing. The syllabus given elsewhere promises an interesting and instructive session; and it is to be hoped that a large additional number of members will be able to profit by participating in it as the result of the present appeal. The small membership fee of 5s. per annum should certainly not be a deterrent. What has been said in regard to one division of the particular Association concerned applies in large measure to the other, and also to the similar organizations south of the Tweed. They afford to the junior members of the profession opportunities not only of acquiring knowledge but of showing its possession.

Australian Gas Matters.

One aspect of labour troubles of the kind which terminate in the ceasing of work was revealed by Mr. G. J. Cohen, the Chairman of the Australian Gas Company, when addressing the annual meeting of shareholders in Sydney—that is, the question of cost to the consumers. The disastrous Australian coal strike, which is now a matter of history, resulted in enormously high prices having to be paid for such supplies of coal as were procurable. The Board, under the circumstances, reconciled themselves to the necessity of meeting large demands in the way of additional outlay; but the losses eventually proved heavier than even they had anticipated. The total sum which the Company lost in this manner is put at over £70,000; but in spite of this heavy handicap, the price of gas was not raised. This is a point in the Company's favour which the customers should remember; and another fact which should not be lost sight of is that, notwithstanding the difficulties experienced in securing sufficient quantities of coal, the gas supply was not allowed to fail. Fortunately, owing to the strong financial position of the undertaking, it has been found possible (by making a substantial call upon the reserve fund) to maintain the dividend at the usual rate; but this does not render any less deplorable the big outlay of money of which the strike was the direct cause. Turning to the Company's own business, it is pleasing to note that during the past half year the increase in consumption amounted to nearly 8 per cent.; and that, in order that the undertaking may be in a position to cope with the anticipated output of next winter, it has been found necessary to make arrangements for increasing the plant at the manufacturing stations. The larger consumption has been the consequence of a substantial addition to the number of consumers on the books—the present total being 92,644. As will be noticed from our report of the meeting, the day consumption of gas is equal to about 46 per cent. of the total deliveries.

The Miners' Unsettlement.

When the papers are filled with references to labour unsettlement, it is pretty safe to assume that affairs in the South Wales coalfield will be found to have a place in the statements made. The present occasion, when the eyes of the industrial world have suddenly been drawn to the lock-out of the boilermakers in the shipbuilding yards—a drastic action by which the employers are seeking to impress on the men the obvious fact that an agreement solemnly entered into should be binding on both parties to it, and not only on one—affords no exception to the rule. The business of the great shipbuilding firms of the North is to be temporarily disorganized; and sections of the Welsh miners are also busy in endeavours to paralyze their own trade. The difficulty which is now perceived so clearly in connection with this colliery district, and the likelihood of which cropping up at some time or another has long been foreseen by many who have watched the course of events, is that of the men getting out of hand with their own leaders. Last month reference was made to the restiveness shown by the men under the policy of the Executive of their own Federation. At that time the Federation had had to decline financial assistance to certain miners owing to the manner in which their unemployment had been brought about; and from a statement made to a Press representative a few days ago by Mr. D. A. Thomas, M.P., it seems that matters are becoming more disturbed as time goes on. Alluding to certain miners who are on strike, Mr. Thomas says: "I am certainly not going to beg the men to return to work. I have fought their battles for them so often inside and outside the Conciliation Board that they ought to have no doubt of my mental attitude towards them. I am tired of all this bickering, and I certainly shall not go out of my way on the present occasion to secure peace which seems impossible of any permanency under existing conditions. The men seem to be as much at war with their own leaders as with the employers; and, as they appear unwilling to carry out the agreement entered into on their behalf only a few months ago, they must abide by the consequences. Time will tell what these consequences may be. I can only add that the employers are heartily tired of all these local bothers." This is significant; and equally so is the assertion of Mr. W. Abraham, M.P., that this kind of indiscipline will sap the whole fabric of national negotiations and agreements, because it must in the long run destroy that confidence in the authority of the parties without which every agreement is so much waste paper. This, of course, is at the root of the whole matter. The trouble in South Wales is largely, on the surface, the old one of the non-Unionist, and the desirability of including him "in the fold." But in reality the question to be solved is between the Unionists and their own Federation. If the masters cannot rely upon the employees keeping strictly to agreements entered into with their accredited (for the time being, at least) representatives, the whole structure of conciliation which has been so laboriously built up must of necessity fall to the ground, and the owners must seek other and less pleasant means of enforcing their views.

The Contract for Glover-West Vertical Retorts at Sydney.

The details of the contract for the Australian Gaslight Company of Sydney (New South Wales) have been finally agreed and settled by Messrs. William Coward and Co., their London Agents, with the West Gas Improvement Company, Limited; and preparation for the retort-house at Mortlake—in which the instalment of West-Glover vertical retorts is to be erected, as already mentioned in our pages—has been put in hand. There will be 56 retorts comprised in this section, in benches of eight each, worked with all the experience of the system on the part of the inventors gained from their earlier essays. The coal in use in the Sydney works is vastly superior to some that has been used with success for verticals in England; and it may be expected that excellent results will ensue. There is an impression in the "old country" that the colonies are to some extent behind the times in carbonization and distribution; but Messrs. Coward and Co., who are the Agents for a number of gas undertakings in both Australia and New Zealand, assure us this is not the case; and that they are now engaged in supplying every sort of the latest inventions and appliances in all departments of gas manufacture—not only as the outcome of their own suggestion, but as the result of the knowledge, even in the most distant of our dependencies, and of the educated opinion of engineers who have studied the problem of coal gas making and distribution in its present advanced and scientific form. With the above installation at Sydney will be a new supply of mechanical coal-breakers worked by electricity, amply sufficient to deal with the coal, which is in exceptionally large blocks; and the works, when the present enlarged appliances are carried out, will be in the front rank of such undertakings, and second to none in the realization of the most up-to-date methods.

Alderman William Groom, the Chairman of the Harwich Gas Company, and eight times Mayor of the borough, whose death was announced in the "JOURNAL" for the 7th of June last, left estate valued at £68,059 gross, with net personalty returned at £55,353.

GAS STOCK AND SHARE MARKET.

(For Stock and Share List, see p. 670.)

BUSINESS on the Stock Exchange last week was quite quiet and destitute of any strongly marked feature. The end of the long account was reached at last, to the general satisfaction. In spite of the dormant character of the week, there was a fairly good tendency throughout. On the opening day, preparations for the settlement repressed active new business; but the tone, on the whole, was pretty good. Consols were no better; but Rails were firm. The American market, too, was stronger on a good lead being given from New York. There were bright spots in the speculative lines also. Tuesday was much the same—quiet but firm. Consols were unchanged; but Rails showed rising prices. Americans looked doubtful towards the close. On Wednesday, the adjustment of the settlement gave rise to no complications. Gilt-edged lines were firm; Rails rather less so. Americans swayed about uncertainly. Business on Thursday was at a low ebb; but there were some advances in prices, aided in a measure by the Bank rate remaining unchanged. Consols were put up, and Rails were firm; but Americans were depressed. Markets were almost quite idle on Friday; and some little realization tended to flatten prices. Consols lost their advance of the previous day, and Rails were annoyed by the labour trouble in the North. The Markets were thinly attended on Saturday. New York was closed and could administer no spur; and things closed pretty much the same as they opened. In the Money Market, rates were easy at first, but afterwards they hardened, only again to give way before the end of the week. Business in the Gas Market was quiet, but not more so than might be expected at the end of August. Changes in quotation (except variations *ex div.*) were few. All were, however, uniformly upward; and prices were very firm. In Gaslight and Coke issues, the ordinary was quite steady at from 105⅛ to 106. In the secured issues, the maximum realized 87½ and 88, the preference 103¾ and 104, and the debenture 80¾. South Metropolitan was quiet and unchanged, with transactions ranging from 120½ free to 122. The debenture was done at 79½. In Commercials, there was one deal in the 4 per cent. at 105¾. Among the Suburban and Provincial group, Alliance and Dublin changed hands at 82⅞ and 83 (a rise of 1), Brentford old at 249, British at 44⅝ and 44⅞, and South Suburban at 121½. On the local Exchange, Chester realized 110 (a rise of ½), and Liverpool debenture 105¾. In the Continental companies, Imperial was unchanged at from 184¼ to 185¾, Union made from 95 to 96¼, and European fully-paid from 23⅝ to 23⅞. Among the undertakings of the remoter world, Primitiva was done at 7 1/16 and 7⅜ (a rise of 1/16), ditto preference at from 5 3/16 to 5 5/16, and River Plate debenture at 97½ and 98¾.

ELECTRICITY SUPPLY MEMORANDA.

Alleged Ignorance of the Manufacturers of Electrical Appliances—Omniscient Marylebone—Reflections of Parliamentary Promotions—Persistent Cloud—Depreciation and Income-Tax.

"FOOLS all of you." That is the sum and substance of the criticism of the manufacturers of electric cooking and heating apparatus that has appeared in letters in the electrical press from the side of the purveyors of electricity, following up the article and letter respectively of Mr. M. Farrer and "Iconoclast," to which reference was made in the "Memoranda" for Aug. 23. The nescience of the domestic electrical apparatus manufacturers, we are asked to believe, is appalling. They know nothing of the requirements of the users of such apparatus; and they go on, happily or otherwise, making goods for which there is no request or sale, and which will not accomplish what is required. The reward for their good but ignorant intentions can only come in the great hereafter. One can but think, from the strain of the criticism of these manufacturers that they—many though they may be, including their staffs and workpeople—know nothing of the requirements of users of such appliances because they do not employ them themselves. Of all people manufacturers surely use their own appliances, if only for the purpose of showing belief in them, and gaining some experience. If they do not, perhaps they show wisdom in refusing to gain experience by personal use, expense, and annoyance. We have really much sympathy for the manufacturer of such appliances, and, in the great breadth and depth of our sympathetic nature, there is profound sorrow that the purveyors of electricity have been so ready to saddle these makers with all the blame for the impotence of electricity to compete in cooking and heating on level ground with gas. The limitations of the manufacturer are great, his difficulties are many, and, as "Meteor" of "domestic electrification" fame truly says, no man in connection with this subject of the production of electrical cooking and heating apparatus "is yet in a position to suggest a lightning reformation."

One or two persons have had the temerity to look at the subject, and print their views, from the standpoint of the much-abused manufacturer; and it is seen from what they say that the critics do not give the manufacturers much assistance by practical suggestions, or afford much aid towards cheapening the cost of turning out the apparatus. To get to the lowest possible cost in use, electrical cooking and heating appliances must be made in anything but a cheap and nasty manner. Cooking-ovens, for instance, must be well-jacketed, so as to show no appreciable loss from radiation, and due regard must be paid to the regulation of the heat; and altogether their design and construction must be of an infinitely more elaborate character than in the case of gas cooking-stoves. Mr. C. H. Archer, one writer from the side of the manufacturers, goes so far as to say that he "does not think it will ever be possible to manufacture electric cooking-stoves at the same cost as gas cooking-stoves." We are not surprised at this. Similar home-truths have been uttered by Mr. M. Farrer, one of the writers who has let loose upon all the insane writing there has been in our electrical contemporaries on this subject of equality in cost and efficiency with gas in cooking and heating. He observes that, while electrical cooking is in the "experimental stage," one "can hardly expect manufacturers to compete in price with the gas-stove, which can be turned out in thousands to a standard design." All things in the electrical line require a long experimental career. Yet another misfortune of such electrical appliances, pointed out by Mr. Farrar, is that one "cannot turn out a standard article which is right for use without alteration on any electricity supply in the United Kingdom."

We had expected that the article and letter that started this correspondence would have brought down a perfect avalanche of abuse upon the authors for their colossal impudence in letting the cat out of the bag. But nothing of the kind. The want of economy and of inefficiency is generally admitted. We use the word "generally" advisedly, for in one quarter there is not agreement. With one accord, however, the manufacturer is made the scapegoat. But why the electrical industry and the manufacturers did not in their distress turn to Marylebone for advice, we cannot divine. There is no difficulty there. Oh, no! There has been; but then (according to a letter by Mr. H. H. Holmes) the wise ones of the Marylebone Electricity Department have shown at least one manufacturer how to construct an electric oven, and now they have one which, with electricity at 1d. per unit, can cook as cheaply as a gas-oven with gas at 2s. 8d. per 1000 cubic feet. Something like 31 cubic feet at that price can be bought for 1d., and will give about 15,000 B.Th.U. We wonder where the difference between this figure and the B.Th.U.'s obtainable by using a unit of electricity goes to. Evidently, taking Mr. Holmes seriously, there is very great disorder in the economy of things in the gas industry. We have not observed since the appearance of the letter from Marylebone that there has been any fund started for commemorating the eminent services to the electrical industry of Messrs. Seabrook and Holmes, or should it be Holmes and Seabrook? That is a serious oversight, which ought immediately to be remedied.

A review of the Private Bill Legislation of the session in the "Electrical Review" shows distinctly the trend of things electrical in this country. Fresh legislation in which electricity is concerned now deals almost exclusively with tramways and railways. The promotions in the still unexpired session of Parliament that treated of ordinary town supply were very small eggs, and but few in number. Our contemporary ascribes this state of things to the feverish activity of some years ago which, it says, was bound to be followed by a period of comparative stagnation. There was no question, during the "feverish activity," of a long period of stagnation succeeding. The "feverish activity" was due to an inordinate belief, built upon the shallowest of grounds, in the future primary illuminating agent of this country being electricity, and to the local authorities, large and small, being misled into thinking that electricity supplied the means by which profits could be diverted from the gas industry to be (so said) used for the relief of rates, but, more correctly stated, for pandering to their own love for prodigality at other people's expense. They were also, in numbers of towns, easily misguided into putting down works, at heavy capital expenditure, on a scale that has been proved to be largely in excess of requirements, and made still more so by the advent of electric and gas lamps of greater economy than those in existence when the electricity works were started. Had gas stood still, and effected no progress in widening the relations of gas consumption and efficiency, the electricity industry would have progressed by leaps and bounds with their metallic filament lamps. The excessive plants at the generating stations that excited imaginations allowed to be constructed—in many towns purely residential—would have been long since insufficient for the demand; success would have led to the throwing out of fresh cables from the distribution system into new districts; and year by year additional powers would have had to be sought from Parliament to enable this to be done. But the "best-laid schemes of mice and men"—and these were not of the best laid—"gang aft a-gley," with the result, as our contemporary remarks, "both electrical companies and municipal bodies have been content to mark-time, and the result is reflected in the Committee rooms of Parliament." We do not see any particular appositeness about the use of the term "content" in this connection, seeing that the position in which electricity suppliers at present stand is a compulsory one. Excepting powers for tramways and railways, the session's promotions look somewhat of the weakling order.

The "marking-time" is not only seen in large portions of the electricity-supply industry, but in the electrical apparatus making industry. The cloud continues that has rested over the latter for so long. At one time there was talk of rifts in the cloud, and of rays that inspired hope. But these were purely chimerical; and, in places in the manufacturing industry to-day, there is a positive

note of despondency. The manufacturing companies that have done best latterly are those whose operations have a broad and diverse basis—like the General Electric Company, whose business extends to telephones, the manufacture of Osram lamps, and in many other directions. But take Crompton and Co., they had a loss last year, after providing for depreciation and repairs, of £20,493; and this is placed at the door of the keen competition that exists for the work that is going. In order to keep life in their establishment, the Company have had to take business at mere works' cost, and have had to exercise rigid economy in every direction of administration. Take Edmundson's as a further example, they are reducing their capital, at the expense of wiping out their reserves. Though a net profit of £10,768 was made last year, this is being carried forward. The Company are financially interested in a number of electricity supply companies; and these have only presented a "fairly general" improvement, while two of them, Bromley and Scarborough, have shown an actual decline in profits. Partly accounting for the "fairly general" improvement have been the inclement weather and the lower coal prices. But these are unreliable conditions—in fact, coal prices have been already ascending. While, too, it is considered by those upon whom the administration of the Company's affairs depends that the metallic filament lamp has come as a boon and a blessing to the industry, the Chairman of the Company thinks its adoption will be more gradual in private residences than it has been in the case of shops. He is a philosophic man; and his experience ought to enable him to judge. But, regarding shops, the adoption of the metallic filament lamp has been more in the direction of the eviction by it of the carbon filament type than of any fresh equipment. Generally speaking, the shares of electrical manufacturing concerns, under the present conditions, will not appeal to investors.

One of the subjects that has of late been troubling the gas industry has been that of the allowance for depreciation in assessing for income-tax; and it has been noticed, with a certain amount of wonderment, not unmixed with resentment at the preferential treatment, that the Inland Revenue authorities have shown special favour to electricity supply undertakings. Why there should be this difference is not apparent; but it exists. A case in point is the Hammersmith electric supply undertaking. It appears from a statement in one of our electrical contemporaries, that for some time past negotiations have been proceeding between the Borough Council and the Inland Revenue authorities with the view to obtaining an alteration in the basis of assessment of the profits of the undertaking for income-tax. The facts, as stated, are these: Up to 1904-5 it was the practice to allow from the gross profits a fixed sum of £2500 to cover depreciation of machinery and plant. This was considered insufficient, and a claim was made for a larger allowance. The upshot is that it has been arranged to allow each year fixed percentages on the capital outlay on mains and machinery of 3 per cent. and 5 per cent. respectively. No income-tax has been paid since 1904-5; but for the three years ended March, 1908, £1920 5s. 4d. has been set aside to meet the liability. On the basis now arranged, the income-tax payable in respect of these years will be £1298 14s., or £621 11s. 4d. less than the amount provided. What the Inland Revenue authorities have allowed here is what they seek to disallow in the case of gas undertakings.

PERSONAL.

On the evening of Monday of last week, Mr. J. D. Smith entertained the staff and workpeople in the Stirling Gas-Works to supper. Mr. J. Johnston, the oldest employee, in the name of the staff congratulated Mr. Smith on his appointment to the important position of Manager at Belfast, and presented him with a roll-top desk as a token of esteem. Mr. Smith appropriately returned thanks.

OBITUARY.

The "Journal für Gasbeleuchtung" reports the death on the 15th ult., after a long and painful illness, of Herr G. F. Schaar, Manager of the Thuringian Gas Company, of Leipzig. Deceased was the founder of a well-known German calendar for gas and water engineers, which he edited for many years, and which still goes by his name.

The death is announced of Alderman Leonard Wild, who for some years was Chairman of the Gas Committee of the Bolton Corporation. He was in his 85th year, and had been a member of the Town Council ever since 1893. At the funeral, the Gas Committee of the Corporation were represented by Councillor Webster (the Chairman), Alderman J. Seddon, and Councillors Gee and Sharples.

The death occurred last Tuesday at North Ormesby, Middlesbrough, at the age of 65, of Mr. James Hanks, a well-known resident on Teesside. He was a brick manufacturer at South Bank, and for many years took a keen interest in public life. He was Chairman of the South Bank and Normanby Gas and Coke Company, Limited, and a Director of the North Ormesby Gas Company. In 1903 he was made a Justice of the Peace for the North Riding.

AN ENGINEERING EXHIBITION

Now Being Held at Olympia.

At the present time Olympia is the scene of yet another exhibition (which will remain open until the 26th inst.), at which are to be seen a large number of things that are of special interest to those connected with naval, mercantile marine, and general engineering and machinery. With so wide a scope, it may be confidently predicted that the show will draw a very large number of visitors; and, indeed, there is much to be seen that will appeal, not only to engineers, but to the general public. A representative collection of models of ships is on view; and there are demonstrations with apparatus designed for rescue work in mines and foul atmospheres, as well as for deep-sea diving. Buyers and users of machinery and power tools, too, have an opportunity presented to them of examining at leisure the latest labour-saving appliances for the equipment of workshops and factories. The patrons of the exhibition and the members of the Advisory Council represent every side of the engineering industries, and include many really influential names. It may be remarked that arrangements have been made for several engineering and technical societies to hold meetings at Olympia during the period of the exhibition—among them, the Junior Institution of Engineers to-day, the Society of Engineers on the 21st inst., and the Association of Engineers-in-Charge on the 24th inst. The educational side has not been neglected; and facilities which are certain to be appreciated are offered to students connected with the various engineering institutions, technical institutes, &c., to visit the exhibition under the guidance of experts. Arrangements have also been made for the admission at specially reduced rates of workmen and employees connected with the principal dockyards, works, and engineering establishments. The present exhibition is the third of the series. The first in 1906 would appear to have consisted principally of a display of machine tools; at the second, in 1907, the heavier side of the engineering industries was represented on a larger scale; while now the scope has been still further enlarged by the inclusion of marine engineering work. The President of the exhibition is Sir David Gill, K.C.B., LL.D., D.Sc., F.R.S., President of the Institution of Marine Engineers; while the Organizing Manager is Mr. F. W. Bridges.

The opening ceremony was performed last Thursday by the Marquis of Graham, who delivered an address which was much enjoyed by the large company present. He remarked that nowadays a man who wanted to become a thorough engineer must have a knowledge of many sciences; and he then went on to dwell upon the services rendered by the profession to the world at large. Our very existence to-day, he pointed out, depended almost entirely upon the machinery which was the outcome of the brains of engineers. In proposing a vote of thanks to the Marquis, Captain H. Riall Sankey, alluding to the remark that an engineer needed a knowledge of many sciences, expressed the opinion that if a man wanted to get on he should stick to one thing; and, in seconding the vote, Mr. W. F. Reid, the President of the Society of Chemical Industry, drew attention to the many directions in which the chemist was of constant assistance to the engineer.

A luncheon followed, at which there was some little speech-making. The toast of "Success to the Naval, Mercantile Marine, and General Engineering and Machinery Exhibition," was proposed by the Hon. John M'Call, M.D., Agent-General for Tasmania, and responded to by Captain Sankey, who pointed out that the idea of the organizers was not merely to make a show, but to bring manufacturers and their clients into closer touch. "The Engineering Industries" was submitted by Mr. J. W. Helps, ex-President of the Institution of Gas Engineers, who remarked that when he was asked to propose this toast his first thought was that it was an error of judgment to place it in the hands of a gas engineer. After a little consideration, however, he realized that the error was not so apparent as it had at first seemed, because the gas industry had perhaps taken as much advantage as any other of engineering progress. This could be seen if they compared the state of things which existed twenty or thirty years ago with what was to be found now in well-equipped gas-works. The progress that had been made in engineering matters in gas-works within this period had been not only very striking, but almost startling. Twenty years or so ago, the labour was manual, and mechanical appliances in this connection were conspicuous by their absence; but now all this had been altered. There was machinery for stoking, and dealing with the coal and coke; and thereby the cost of gas production had been greatly decreased. Therefore, gas engineers were foresighted enough to fully appreciate the progress made in engineering during recent years. With regard to motive power, in his own works he had gas-engines, electricity, steam, hydraulic power, and compressed air; and when they considered this and all the splendid machinery that was in use in gas making, &c., they would realize the truth of his assertion that gas engineers had not been behind anyone in taking advantage of the great modern advances in engineering. Going back to 1889, he found that, to produce the whole of the gas that was made in his own works, they employed 112 men; and notwithstanding the fact that during the ensuing twenty years the output of gas had increased by somewhere about 250 per cent., the number of men engaged in

manufacturing it had only grown to 189. This was a very striking fact; and the increased adoption of machinery had enabled the work to be done, not only far more economically, but with much less arduous labour on the part of the men employed. It was urged, he knew, that the introduction of machinery had had a lot to do with the great amount of unemployment which was prevalent in this country. In connection with his own industry, he could refute this idea, because, while the introduction of machinery had undoubtedly enabled them to make gas and to sell it at a much cheaper rate than was formerly possible, still this cheapening of the cost had caused gas to be used for many purposes that were impossible before; and in looking after the distribution of this greater quantity of gas and in attending to the wants of the customers, a far greater number of men were employed than used to be the case. Taking his own Company, in 1889 the average weekly number of men employed in the distribution department was only 33; whereas in 1909 this number had increased to 241. So that putting the manufacturing and distribution departments together, it would be found that the actual number of men who were employed now, in spite of the altered methods of manufacture, was absolutely *pro ratâ* with the increased output of gas. In reply, Mr. Mark Robinson remarked that nowadays there was no industry in the country which was not indebted to mechanical engineering. Referring to the Brussels Exhibition, he said the show which we made was not that which England ought to make. Those who had great businesses, and had perhaps made great fortunes from them, should remember that they owed something to their country, and should come forward on such occasions to a greater extent than they seemed inclined to do. However, the Humphrey gas-pump was one exhibit of which they should all be proud. He himself believed that the internal combustion engine was going to do very great things in the future.

So far as the exhibits themselves are concerned, though there is, of course, much that is of interest to all mechanical engineers, there is not a great deal that appeals to persons identified with gas and water works more than to those connected with other commercial undertakings. The generally appreciated naval department and the excellent show of machine tools naturally account for a very considerable proportion of the space filled up. Gas lighting itself is worthily represented by the Tilley High-Pressure Gas Syndicate, of Kingsland Road, who have a large stand brilliantly lighted by incandescent lamps furnished with gas on their system—which, as they remark, was "invented with a view to supplying a widespread demand for a better and more economical means of illumination, suitable for both small and large users of gas." The compressors, which are extremely compact, and automatic in action, are shown in three types—belt-driven, electric-driven, and water-driven. Appliances for the utilization of acetylene gas in various ways are exhibited by the Acetylene Illuminating Company, the Imperial Light, Limited, the Thorn and Hoddle Acetylene Company, and Messrs. C. C. Wakefield and Co.; while the petrol air-gas plant of the Praed Patent Safety Gaslight Company is also to be seen in action. As for gas-engines, these are shown by Messrs. E. S. Hindley and Sons, of Queen Victoria Street, E.C. (a 75 B.H.P. vertical three-cylinder gas-engine for direct coupling to an electric generator, centrifugal pumps, &c.), and Messrs. Kynoch, of Birmingham (a 100 H.P. gas-engine, which is seen running, in addition to some other plant).

A stand which was securing a considerable amount of attention at the time of our visit was that of the Cambridge Scientific Instrument Company, who make an imposing display of pyrometers, thermometers, Méker burners, and furnaces, &c. Most of the apparatus is shown in operation; it being possible, for instance, to watch the method of taking readings of furnace temperatures by means of the Féry radiation pyrometer. Many of the visitors, too, walked out into the yard to inspect the Babcock and Wilcox patent portable type water-tube boiler, which has been fitted up for the purpose of supplying steam for driving machinery in the exhibition. The Lea Recorder Company, of Deansgate, Manchester, have in action one of Lea's patent combined indicating, recording, and integrating instruments of the latest pattern, which is engaged in measuring the discharge of one of the pumps on the Worthington Pump Company's stand. Messrs. Wallach Bros., of Finsbury Square, among many other things, show their "Ever Trusty" whitewashing machines; and Messrs. Gwynnes, Limited, of Hammersmith, some pumping-engines. Elsewhere there is to be seen the Kennedy bending machine, invented by one of the employees of Messrs. John Barker and Co., of Kensington, to bend tubing, but which it has been found is suitable for manipulating metal generally. There are indicators for steam and gas engines on the stand of the Crosby Steam Gauge and Valve Company, of Queen Victoria Street; and the "Fournier" thermo instruments (by means of which any degrees of temperature, humidity, and ventilation can be indicated, recorded, or regulated at any distance), at that of Messrs. F. Mellin and Co., of Kilburn. Another stand which attracted notice was that of Messrs. George Kent, Limited, of High Holborn, where meters of various kinds—including the Venturi principle—are a feature. One ingenious piece of mechanism is an alarm for indicating the occurrence of a burst in a water-main; the alarm consisting of a bell which rings continuously for several minutes on any pre-arranged reduction of pressure taking place. Finally, it may be mentioned that the British Oxygen Company, of Elverton Street, S.W., give, among others, daily demonstrations of oxy-acetylene and oxy-coal-gas welding.

SCIENTISTS' VIEWS ON GASEOUS EXPLOSIONS.

Discussion on the Third Report of the Gaseous Explosions Committee of the British Association.

We give in another part of the "Journal" (p. 640) the full text of the third report of the British Association Committee on Gaseous Explosions, which was presented by Professor Bertram Hopkinson, one of the Secretaries of the Committee, in the Engineering Section last Friday.

Before the discussion of the report was commenced,

Professor H. B. Dixon submitted a short sketch of some work he has carried out recently on the photography of the firing of gases by adiabatic compression, and exhibited some photographs of this character. The experiments were directed to showing that the general opinion that gases ignite by detonation is not correct, but that with ordinary gas-engine mixtures the flame spreads gradually: and the photographs brought this out well. Another point dealt with was the pre-flame period; and in these experiments a carbon disulphide oxygen mixture was employed. The resultant photographs showed a quite considerable period between the ignition and the flame. Other photographs demonstrated that sound waves in the tube could be photographed; and these also showed almost an absence of sound waves after the gas was ignited. Perhaps, said Professor Dixon in conclusion, some opinions would be expressed as to whether conduction and radiation losses were likely to arise in his experiments, and likewise whether loss of heat could happen while the gases were being heated up.

Mr. Dugald Clerk, speaking on this point, said that experiments he had carried out showed there would be considerable loss of heat during compression; but though this increased with the piston speed, it did not increase in proportion to the increase of the piston speed. For this reason, he thought it possible that the real temperatures shown by Professor Dixon were higher than those he had given. He eulogized the work of Professor Dixon and Professor Hopkinson in connection with the phenomena of gaseous explosions, and also the work of the Committee. For a long time considerable doubt had, he said, existed concerning many facts relating to the internal combustion engine; but the work of the Committee was gradually clearing them up. For instance, it was now definitely settled that the specific heat of the working fluid increased with temperature. The Committee's work had also shown that radiation losses were larger than they had thought—a question upon which there could not now be much doubt, in view of the remarkable manner in which the experiments of Professors Hopkinson and Callendar coincided. Their original views upon the transparency of the flame had to be modified; for they now knew that it was transparent to its own radiation. Upon several other points also, the experimental work now going on rather pointed to the danger of applying the laws governing the loss of heat in a fixed and closed vessel to a vessel which contained a moving piston. The advantage of investigations being carried on by a committee was that it enabled much more rapid progress to be made than when the work was left to individuals.

Mr. H. E. Wimperis emphasized the great practical importance of definite information as to what extent the glowing gas is transparent to its own radiation. He pointed out that gas-engines are rapidly increasing in size; and this fact alone, he said, called for further investigation of the matter.

Dr. E. G. Coker thought the results of Professors Hopkinson and Callendar were not quite in agreement as to the degree of transparency of the flame to its own radiation. He believed the lateral extension of the flame was the main cause of the difference. Another interesting matter was that the activity of the radiation was very much increased at the point of dissociation. The question of turbulence was also of considerable importance.

Captain H. Riall Sankey referred to the polishing of cylinders and pistons, and mentioned that Messrs. Sulzer had been in the habit of doing this. The Committee's experiments upon radiation had been in a comparatively small vessel, and what was really wanted was to arrive at results obtained in an actual gas-engine cylinder.

Dr. Rosenhain, referring to the experiments of Professors Hopkinson and Callendar, pointed out certain differences in the methods adopted. Professor Callendar had, he said, used a number of flames a short distance apart; while Professor Hopkinson employed a continuous mass of flame. Consequently, with the Callendar experiments, the factor of reflection due to the radiation from the first flame did not arise in the case of the Hopkinson experiments. He also suggested the possibility of introducing vapour into the combustion chamber which would absorb the radiant heat, and so obviate some of the losses which had been referred to in this connection.

Sir William White, K.C.B., in a short speech, referred to the recent articles in the Daily Press regarding gas-driven warships, and remarked that if the writers only understood the practical difficulties in the way of such a naval development, they would realize that it was a long way off.

Professor Hopkinson, in reply, thought the factor which had contributed most largely to the variation in the results obtained by Professor Callendar and himself was the difference in the size of flame adopted.

THE BRITISH ASSOCIATION AND GASEOUS COMBUSTION.

Discussion on Dr. Bone's Report.

In another part of the "Journal" (p. 648) will be found the full text of the report presented by Dr. Bone, on the subject of "Gaseous Combustion," at a joint meeting of the Physical Science and Chemistry Sections of the British Association last Friday. It led to an interesting discussion, the principal features of which are given below.

Dr. Bone, in laying the general results of his report before the meeting, said it had been prepared mainly in order to get the views of the physicists upon the problems which had now to be solved. For instance, on the influence of moisture upon combustion there was much disagreement, even between the chemists themselves. In fact, he did not think there had been a question during the past twenty years on which there had been so much diversity of view; and they had not yet arrived even at a partial agreement. Dr. Bone somewhat amplified Section VI. of his report, which dealt with the influence of hot surfaces upon combustion. He said he had reason to believe that in the firing of furnaces, and so forth, the surfaces played a very important part in the development of concentration of the heat. There was no doubt whatever that hot surfaces did accelerate combustion as they accelerated other changes in gaseous systems. It had long been known among technologists that surfaces accelerated dissociation. The subject was developed very considerably on its experimental side during the first thirty years after Davy's death; but, for some reason or other, interest in it waned, and was not revived again till about fifteen years ago, when some German workers took it up and tried to develop it on its theoretical side. In the experimental inquiry, it was necessary to prosecute the experiment under conditions where surface combustion was not interfered with by combustion taking place in the main body of the gas; otherwise the effects were too complex for analysis. They were therefore limited at present to the investigation of the phenomenon below the ignition-point. In this connection, Dr. Bone threw upon the screen some micro-photographs of silver gauze before and after it had been hydrogenized. It was shown that after such a surface had been used for surface combustions, and repeatedly accelerated by exposure to hydrogen, the surface had the appearance of being completely frosted; showing that the combustion had been due to actual association of the gas with the surface. Apparently only the hydrogen and the surface were concerned; but whether this was so at high temperatures it would be rash to say. It might be that the position would be reversed. With people who had investigated combustion at high temperatures, it seemed that there were some results which indicated that the oxygen also began to exercise an effect; but this at present could not be stated quite definitely. One fact recently found with regard to surface combustion must be considered in connection with the influence of moisture. Professor Dixon found thirty years ago that dry carbonic oxide and oxygen were not inflammable. He (the speaker) found that carbonic oxide, thoroughly dried, accelerates surface combustion in a very marked degree. If they took a mixture of carbonic oxide and oxygen, and saturated it with (say) 1½ per cent. of moisture, a certain value would be obtained—*i.e.*, a certain amount of gas would disappear in a given time. If this mixture were thoroughly dried, it would be found that the value obtained before was about doubled. In other words, the removal of the trace of moisture had the effect of very greatly accelerating the action of the surface in bringing about the combustion of the carbonic oxide. He had also found that these metal surfaces became electrically charged while surface combustion is proceeding. There was a very distinct electrical charge on the surface when combustion commenced, and, so far as could be ascertained at present, this charging-up synchronized with the beginning of the surface combustion. He thought this was roughly true, though it was difficult to determine when combustion occurred. With regard to the influence of the surfaces in this connection, there were indications that it was connected with the well-known property of surfaces giving off charged particles when highly heated.

Discussion.

Professor Sir J. J. Thomson, F.R.S., in opening the discussion, first referred to the velocity of propagation of explosive waves. In dealing with this subject, he pointed out that the meeting was not merely considering separate atoms and molecules, as there were much smaller and much more rapidly moving bodies than the atoms and molecules of an ordinary gas to be taken account of. It was quite possible that these moved forward in front of the explosive wave, prepared the gas in front of it for the explosion, and put it in a condition in which it was ionized, and in which the chemical processes might occur much more rapidly than in a gas that was quite unsophisticated, and had not been under the influence of these particles. If this were the case, he thought they could stop these particles moving by producing a magnetic field, as they would be unable to get across it. It would be very interesting for experiments to be carried out to ascertain whether, if the tubes in which these explosive waves were studied were placed in a strong magnetic field, any influence would be produced upon the velocity of the propagation of the wave or upon the velocity with which the explosions were prosecuted. In regard to the influence of moisture upon combustion, if there were small particles of water present, they would certainly diminish the attraction between any electrified bodies in their neighbourhood. But whether the effect of this dissociation was sufficient to explain what the chemists observed in this connection, he did not know, as he had made very few experiments as to the effect of moisture upon chemical combination. In the course of the past year, some work had been carried out in connection with the presence of small quantities of moisture in gases; and this had considerable bearing on the question, which was also allied to that of hot surfaces. The negatively charged constituent in a gas was a very much smaller mass, and moved with very much greater velocity, than the positive, when it was first produced. But if they took any ordinary gas, and attempted to measure the velocities of the positive and negative constituents, it would be found that the difference was only a few per cents. During the past year certain work at Oxford and in Germany had demonstrated the fact that if the gas were dried—say, by liquid air—there was an immense disproportion between the velocities of the positive and negative. With dried gas, the velocity of the negative might be 100 times that of the positive; and to produce this difference, there was only required an amount of moisture comparable with that needed in chemical combination. This result must have a very considerable bearing on what was an almost identical problem—viz., the combination of different gases. The effect of hot surfaces on the rate of recombination was a subject of very great importance to the physicist, because in recent years very many interesting points had been discovered regarding the emission of positive and negative electricity from heated surfaces. He should like to know whether Dr. Bone had found his heated surface become positively or negatively electrified, either before or during combination. It was a very important matter from the point of view of the physicist, because if it became positively electrified it would mean that the surface had been giving out large quantities of negative electricity. It was known that many surfaces did this. For instance, lime, if heated, gave out an enormous stream of negative electricity. On the other hand, most metals, when heated to these moderate temperatures, gave out an excess of positive electricity. Therefore, from the physical point of view, it was essential that they should know whether in Dr. Bone's case the electrification was positive or negative.

Dr. Bone: It was negative.

Professor Thomson said, that being so, he should rather doubt whether the positive ions would stick to the oxygen. It was not generally found that the presence of these gases had much effect upon the positive constituents. It was the negative ones that showed this extraordinary variation and difference of behaviour if minute impurities were mixed with them. He very much wished that chemists would study the peculiar behaviour of these oxides. Experiments with a piece of lime or a piece of barium oxide would show an immense stream of electricity coming out at high temperature; and anyone making the experiment must be impressed by the importance of the phenomenon. At present he did not think there was any decided answer as to where the energy came from to project these negative particles in such an amount and with such velocity. Was there the possibility of the formation of two oxides, and oscillation between one and the other, giving a liberation of energy which would be available for producing these streams of negative particles? He believed that there were two oxides of barium which might possibly behave in this way; and he was not sure whether chemists recognized corresponding oxides of calcium. There must be some source for this energy; and it was possible that there might be some kind of formation of different oxides which would liberate different amounts of energy. Surface effects had been studied a good deal lately in connection with the influence of ultra-violet light upon metals, and the conclusion was being arrived at that the greater part of the difference in this effect was due to the differences in the gas sticking to the surface. The surfaces were closed with layers of electrified gas; and it could easily be seen that, if there were a positive layer in front, this would tend to prevent the emission of the positive. With negative in front, the tendency was to facilitate the emission of the positive, and the effects obtained with ultra-violet light pointed to the fact that a great deal of the behaviour of the surfaces was due to the formation of a kind of support for layers of electrified gas. He had no doubt this would be found to play a very considerable part in the phenomena of combustion.

Sir Oliver Lodge emphasized the importance of Sir Joseph Thomson's suggestion with regard to the application of a magnetic field to an explosion tube. The photographs of Professor Dixon showed that the compression wave was overtaking the flame wave somewhere; and then it would seem that there was a new explosion or a new kind of chemical combination set up which reinforced the original flame, and formed a fresh nucleus of disturbance. If this were so, it would seem that a different chemical action was going on at this point. The velocity of sound had been mentioned in connection with these gases. But this was not a very definite quantity in these cases; it was influenced so much by the explosive actions going on. A bullet produced a compression wave when it hit the air. An explosion might do something of the same kind; and the velocity of sound might be trebled according to the temperature of the gas. In a Diesel engine, the compression of air could produce ignition—

i.e., it produced very high temperature. The velocity of sound varied as the square root of the absolute temperature. The effect of surfaces upon combustion was of intense interest. It was the action of more or less cool surfaces that was responsible for so much of our smoke. The effect of the surfaces becoming charged was quite new to him; and he hoped it would be investigated. It might be that the positively charged ions given off from the surface were blown away, and thereby left the surface negatively charged.

Professor HAROLD B. DIXON, dealing with the effect of moisture, expressed the view that there were cases where they must look to some action between two or probably three constituents of the gases; and he instanced the case of an explosion of a mixture of hydrogen and chlorine. He said it was clear that there was no obvious chemical action taking place between two of the constituents which started the explosion. They must consider the whole three together; and he thought there was possibly some action of the electrons to be considered. He had experimented with hydrogen and chlorine, and found that the drier it was, the more quickly it exploded. He had tried one experiment with regard to the negative particles sent out by ignition. He dried the oxygen and hydrogen very thoroughly, and used them in tubes dried and undried. After photographing the two flames from the starting-point, he found no difference in the spread of them. Both were fired by a spark, and both spread in the same way. He had also tried the experiment of putting gases in a magnetic field; but he could not detect any difference. At the same time, it would be interesting to carry out the experiment with Professor Thomson's apparatus, and follow it photographically. Perhaps Sir Joseph would tell him how he concentrated the magnetic field so as to draw away the electrons as they were produced.

Professor SMITHELLS thought a point had been reached in the investigation of this subject where the assistance of the physicist was indispensable. Physicists studying Dr. Bone's report would be surprised at the compleness with which the chemical aspect of the phenomenon had been studied. It was difficult to see whether chemistry pure and simple could advance farther. What was wanted now was more information upon the molecular transactions that were taking place.

Professor H. E. ARMSTRONG remarked that little or no progress would be made until chemists and physicists could look at the problem with equal interest. He challenged the opinions of the physicists as to the possibility of any action whatsoever taking place between two molecules neither of which was an electrolyte. He wished to insist upon the need of the presence of an electrolyte as a member of the system within which the action took place; and he advocated the need of dirty water for this purpose.

Sir J. J. THOMSON said physicists had been much perplexed by what chemists meant by an electrolyte.

Professor ARMSTRONG: An electrolyte is a substance which carries a current and is decomposed in it.

Sir J. J. THOMSON: Anything can do that.

Professor ARMSTRONG: No. Can pure water carry a current?

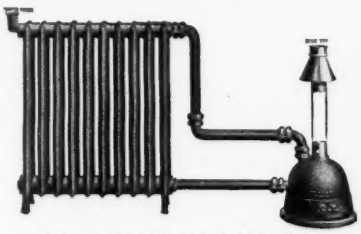
Sir J. J. THOMSON: Yes.

Professor ARMSTRONG insisted that it could not, and he asked for proof. Continuing, he said that the chemists and the physicists were not in agreement upon the fundamental points, and it was these they would have to discuss.

Professor BONE briefly replied to the remarks made.

SOME WELL-KNOWN GAS-FIRES AND A NEW PATENT BOILER.

AMONG the specialities of Messrs. Arden Hill and Co. this year, a noticeable feature is their new patent gas-heated boiler, the "Domas," an illustration of which is given below. It is a small but efficient apparatus, specially designed for the heating of garages, greenhouses, schools, living-rooms, and all places suitable for hot-water heating. It creates an entirely new type, which, owing to its very low gas consumption and effective heating, has overcome all difficulties in the way of the adoption of this method on the score of expense.



"Domas" Boiler "Auto" Radiator.

The "Thorium."

The firm are also looking forward to a busy season with their fine range of "Thermo" fronted stoves, some of which are shown. Prominent among them is the "Versailles." This high-grade fire embodies a novel departure in gas-fire construction in the shape of the wide-fire principle. The "Versailles" provides the same amount of radiating surface as the coal-fire it replaces, and so removes one of the chief disadvantages under which heating by gas hitherto laboured. The patent "Thermo" principle effects this with a proportionally low gas consumption. The series of interchangeable stoves—the "Radium," "Thorium," and "Cerium"—became popular immediately after their introduction; and they are now found on the hiring-lists of a large and increasing number of gas undertakings. The fact that all the removable parts of the firm's stoves are absolutely interchangeable, and therefore common to all, renders them a very desirable group of fires for hiring-out.

The "Versailles."

The "Radium."

The "Cerium."

The "Adept."

Another fire which deserves mention here is the "Adept." This basket-fire, brought up to date, has commanded a wide measure of success, due in part to the embodying of so novel a feature as the patent adjustable grate front. This is much appreciated by consumers, as it is made so as to be readily adjusted at any level, from $3\frac{1}{2}$ inches up to $5\frac{1}{2}$ inches, and so hides from view the often somewnat unsightly ashpan opening of the coal-grate.

Scottish Junior Gas Association (Eastern District).

We have received from the Hon. Secretary and Treasurer of the Eastern District Division of the Association (Mr. W. Geddes, of Granton) the syllabus for the ensuing session, which will open on the 24th inst., at the Heriot Watt College, Edinburgh, under the presidency of Mr. Walter Dunlop, of Kirkcaldy. Ordinary meetings will be held on Nov. 12, 1910, and Jan. 7, 1911; and the annual general meeting—the last of the session—has been fixed for the 18th of March. Visits have been arranged for the following dates: Oct. 15, to the works of Messrs. Henry Balfour and Co. and the gas-works at Leven (Fife); Dec. 10, to Messrs. James Dougall and Sons' Fire-Brick Works, Bonnybridge; Jan. 21, 1911, to the Fife Coal Company's Colliery; and Feb. 25 (jointly with the members of the Western District Division), to the Airdrie Gas-Works.

In connection with the meeting of the British Association in Sheffield, the honorary degree of Doctor of Science has been conferred upon Sir Oliver Lodge, F.R.S., Sir William Crookes, F.R.S., and Sir William Ramsay, K.C.B. The last-named gentleman is President of the Association for the ensuing year; and the annual meeting will be held at Portsmouth.

Among the exhibitors in the destroyed British Section of the Brussels Exhibition who have expressed their willingness, if space can be found for them, to participate in the new section, which is to be opened in the Salle des Fêtes, are the Cambridge Scientific Instrument Company, Messrs. Fletcher, Russell, and Co., the Gaslight and Coke Company, the Glenboig Union Fire-Clay Company, and the South Metropolitan Gas Company. The last-named Company had an interesting exhibit in the shape of a large model in pitch of the Matterhorn, the snow being represented by sulphate of ammonia.

GASEOUS EXPLOSIONS.

Third Report of the British Association Committee.

Before Section G., at Friday's session of the meeting of the British Association, which was held in Sheffield last week, the Committee appointed for the investigation of gaseous explosions, with more special reference to temperatures, presented their third report.

The members of the Committee are Sir William H. Preece (Chairman), Mr. Dugald Clerk and Professor Bertram Hopkinson (Joint Secretaries), Professors Bone, Burstall, Callendar, Coker, Dalby, and Dixon, Dr. Glazebrook, Professors Petavel, Smithells, and Watson, Dr. Harker, Lieut.-Colonel Holden, Captain Sankey, Mr. D. L. Chapman, and Mr. H. E. Wimperis. The Committee recommended that they be re-appointed, and ask for a grant of £100. The first report was given in the "JOURNAL" Vol. CIII., pp. 719, 793; and the second, in Vol. CVII., pp. 766, 834. Six meetings of the Committee have been held—one each at the Universities of Leeds, Manchester, and Cambridge, one at the Imperial College of Science and Technology, and two at No. 57, Lincoln's Inn Fields, by the kindness of Mr. Dugald Clerk. In accordance with previous practice, notes dealing with their current work have been presented for discussion by members of the Committee, as follows: No. 14, Dissociation (A. Smithells and W. A. Bone); No. 15, Ignition Temperatures of Gases (H. B. Dixon); No. 16, Modern Theories of Gases (Sir W. H. Preece); No. 17, Radiation from Flames (H. L. Callendar); and No. 18, Radiation in a Gaseous Explosion (B. Hopkinson).

The report—accompanied by three appendices, on radiation from flames, on radiation in a gaseous explosion, and abstracts of papers relating to Siemens' furnaces—is as follows.

INTRODUCTION.

During the session 1909-10, the experimental work by members of the Committee, to which allusion was made in the second report (1909), has been continued. Mr. Dugald Clerk's measurements of the volumetric heats of air and carbonic acid at ordinary temperatures by the method of adiabatic compression have yielded results in close accordance with those obtained by Swann. The method of division of heat-loss employed by Mr. Clerk in reducing the results was the same as that which he used in his original high-temperature experiments. The correctness of the results obtained at the lower temperatures by this method, goes far to justify its application to the compression and expansion of highly-heated gas. An account of these experiments will shortly be published, and will be quickly followed, it is hoped, by an account of further work on the compression of flame and heated gases on which Mr. Clerk is already engaged. Professor Hopkinson has published a paper on the radiation in a gaseous explosion, to which more particular reference is made later in this report.

A series of experiments on the temperatures of ignition of hydrogen and oxygen produced by adiabatic compression (according to the suggestion of Professor Nernst) has been carried out by Professor H. B. Dixon. It was found necessary to check the descent of the piston mechanically when the "ignition-point" was reached, instead of allowing the flame itself to stop the movement, as in Falk's experiments. With quickly-igniting mixtures, such as electrolytic gas, there is little difference between the results obtained with a freely moving and with a checked piston; but with slowly-igniting mixtures, such as mixtures of hydrogen and air and mixtures with a large excess of oxygen or of hydrogen, there is a considerable difference between the two methods. Thus, while the compression necessary to fire electrolytic gas agrees closely with that found by Falk, the addition of oxygen was found to lower the ignition-point continuously, so far as the experiments were carried. Using the value of γ deduced from Joly's experiments, Professor Dixon finds that the ignition-point of electrolytic gas is 557° C., which is in close agreement with the ignition-temperature determined by Dixon and Coward last year.

Professor Dalby is communicating to the Association an account of his measurements by means of an orifice of the air-supply to a gas-engine. This work, while not bearing directly on the matters under discussion by the Committee, will be of considerable assistance to those who have to experiment on gas-engines and desire to determine the proportion of air in the charge. Professor Coker has made, and will shortly publish, further measurements of the temperatures in a gas-engine cylinder. The Committee hope to be able to discuss Professor Coker's experiments at greater length next year. The Committee are not aware of any important publications on the Continent or in America (during the past year) which bear directly on their work, though mention should be made of a valuable paper by Hans Schmidt dealing with the radiation from a bunsen flame.

ON THE RADIATION FROM GASES.

In the first and second reports of the Committee, reference was made to the part played by radiation in the cooling of the products of an explosion, and to its bearing on the measurements of volumetric and specific heat with which those reports were principally concerned. The general question of radiation from heated gases has, however, from the point of view of the Committee, an interest and importance of its own which are sufficient to justify a detailed study of it in its wider aspects. Radiation plays a part comparable with that of the conduction in determining the heat-flow from the gas to the cylinder walls in the gas-engine; and it is this flow of heat which is the most important peculiarity of the gas-engine, and to which are chiefly due the leading characteristics of its design. Even to the uninstructed eye, the most obvious features about large internal combustion engines are the arrangements for cooling, and the great size and weight for a given power which is necessitated mainly by these arrangements. The difficulties which the designer has to meet are due in the main to the stresses set up by the temperature gradients, which are necessary to sustain the flow of heat. In the present state of the art, it is probable that the most important service which science could render to the gas-engine constructor would be to establish definitely the principles upon which depends the heat-flow from hot gases into cold metal with which they are in contact, and thus enable him to predict the effect on heat-flow of changes in the temperature, density, or composition of the charge, and in the state of the cylinder walls.

The Committee do not propose in this report to deal with the whole of this large question, but will confine their attention to one important factor in heat-flow—namely, radiation. The subject is a wide one, which has excited much attention among physicists and chemists; and on several important points agreement has not been reached. No attempt will, therefore be made to do more than state shortly the experimental facts, and define the issues which have been raised in regard to the explanation of these facts.

PRACTICAL EFFECTS OF RADIATION.

It is believed that the first instance in which radiation from a flame was used in an industrial process, with knowledge of its importance, was the regenerative glass-furnace of Frederick Siemens, which he described at the Iron and Steel Institute in 1184. Here the combustible gas was burnt in a separate chamber, and the hot products of combustion were led into the furnace. The objects to be heated were placed on the floor of the furnace, out of contact with the stream of flame which flowed above them. They would therefore receive heat only by radiation; and it was supposed that this radiation came in a large measure from the flame. Siemens, however, was of opinion (in 1884) that the radiation was due to incandescent particles of carbon, and that there was little radiation froma non-luminous flame.*

In 1890, Robert von Helmholtz measured the radiation from a non-luminous coal-gas flame 6 mm. diameter, and found it to be about 5 per cent. of the heat of combustion. The radiation from a luminous flame was greater, but not very much greater—rising to a maximum of 11½ per cent. for an ethylene flame. Discussing the Siemens furnace in the light of these results, R. von Helmholtz calculated that radiation from the flame in the furnace could only account for a small fraction of the actual heat transmission. He pointed out, however, that a large flame would probably radiate energy at a greater rate than a small one. But while admitting that for this reason gaseous radiation might play a part in the transmission of heat, he suggested that a more important agent was radiation from the roof of the furnace, which received heat by direct contact with the hot gas, and so reached a very high temperature. He showed by calculation that a comparatively small excess of temperature in the roof over that of the floor would cause a sufficient flow of heat.

But though the discussions on the Siemens furnace and the work of Helmholtz show that the idea that a flame, even if non-luminous, might radiate large amounts of heat, was a familiar one to many people twenty years ago, its possible importance in causing loss of heat during and after a gaseous explosion and in determining the heat-flow in a gas-engine does not appear to have been appreciated till quite recently. Professor Callendar was probably the first to draw attention to its significance in this connection. In the discussion on a paper about explosions, read before the Royal Society in 1906, he said that he had found a non-luminous bunsen flame to radiate 15 to 20 per cent. of its heat of combustion, and expressed the opinion that the loss from this cause in a closed-vessel explosion would be of the same order. Professor Callendar's note dealing with this matter is published in full in Appendix A; and it is only necessary to state here that he was led to study the subject by his work on the efficiency of the petrol motor.

There are, in fact, several points about the behaviour of gas-engines which suggest the importance of radiation as a cooling agent. The particular matter which attracted Callendar's attention was the effect of speed on thermal efficiency. His experiments showed that a part of the loss of efficiency in an internal combustion motor, as compared with the corresponding air-cycle, was independent of the speed at which the engine was run. The loss of heat per cycle could, to a first approximation, be represented by an expression of the type $A + \frac{B}{n}$, where n is the number of revolutions per minute and A and B are constants. The term A represents a constant loss of heat per explosion, and among the many causes contributing to this constant loss of heat, radiation from the flame is probably important.

Another phenomenon which is difficult to explain, except as the result of radiation, is the effect of strength of mixture on heat-loss.

* Captain Sankey has prepared an abstract of papers relating to the Siemens furnace. See Appendix C.

The following table shows some results which were obtained by Hopkinson upon a 40-H.P. gas-engine.

Percentage of gas in cylinder contents. .	8·5	11·0 per cent.
Total heat-loss per minute	1510	2300 B.Th.U.
Total heat-loss as percentage of total heat supply	29	34 per cent.
Temperature of piston	300°C.	430°C.

It will be observed that the proportion of heat-loss to the walls increases very materially as the strength of mixture is increased. If the transfer of heat were wholly due to conduction, it might be expected, apart from the disturbing influence of speed of ignition, which in this case was not very important, that the percentage of heat-loss would rather diminish with increase of charge, because the temperature with the stronger mixture should be relatively less on account of the increase of volumetric heat. Increased temperature of piston and valves would work in the same direction. The existence of radiation, however, which increases more rapidly in proportion to the temperature, would account for the increased heat-flow. The practical importance of questions of this kind is illustrated by these figures, from which it appears that the piston is 50 per cent. hotter, though the charge of gas is only increased 30 per cent.

More direct evidence of the importance of radiation is furnished by experiments on the effect of the surface of the walls. In the second report of the Committee, reference was made to the belief which is widely spread among those who are concerned with the practical design and operation of gas-engines, that polishing the interior of the combustion chamber tends to increase efficiency. Some experiments were also quoted in which it was found that lining an explosion vessel with bright tinfoil perceptibly retarded the cooling of the products. More recently an explosion vessel has been plated with silver on the inner surface; and the results have been compared after exploding identical mixtures—first, when the lining was highly polished; and, secondly, when it was blackened over with lamp-black. It was found that by highly polishing the interior of the vessel, the maximum pressure reached could be increased 3 per cent., and the subsequent rate of cooling during its earlier stages reduced by about one-third. These experiments leave no doubt of the reality and of the practical importance of radiation as a factor in determining heat-loss in the gas-engine.

Reference may also be made to the part played by radiation in determining the heat-flow in a boiler. Attention was drawn to this by Dalby in a recent report to the Institution of Mechanical Engineers. The circumstances in this case are widely different from those usually obtaining in the gas-engine; but the instance serves to emphasize the importance to the engineer of the questions which will be discussed in this report.

Amount of the Radiation from Flame.

R. von Helmholtz appears to have been the first to attempt the accurate measurement of the radiation emitted by a flame. He found that a "solid" flame 6mm. diameter, burning coal-gas, radiated about 5 per cent. of the total heat of combustion. A carbon monoxide flame radiated about 8 per cent.; and a hydrogen flame, about 3 per cent. On account of the smallness of the flame, his experiments have not much application to the problem of the gas-engine. The size of the flame affects the matter in two ways. In the first place, a large flame radiates more per unit of area than a small one, because a flame is to a great extent transparent even to its own radiation; so that radiation is received, not only from molecules at the surface of the flame, but also from those at a depth within it. This matter will be further dealt with in another section of this report. The second point is that the cooling of the gas is slower in a large flame than in a small one. The radiation originates in the vibration of the carbonic acid, and steam molecules; and the life of one of these molecules as a radiating body extends from the moment of its formation to the time when its vibrational energy has been destroyed by radiation and by collision with colder molecules—such as those of the air surrounding the flame. The smaller the flame, the more rapid will be the extinction of the vibrations, and the less, therefore, the total amount of radiation per molecule. The products of explosion in a closed vessel or in a gas-engine differ considerably in this respect from any open flame, however large, which it is possible to produce; for they are not subject to cooling by mixture with the outside air. Moreover, the density of the gas is very much greater.

Callendar has repeated some of Helmholtz's experiments on a larger scale, and has found that the radiation in a non-luminous coal-gas flame, 30 mm. in diameter, may amount to 15 per cent. of the whole heat of combustion. Further reference will be made to Callendar's work under the heading of "Transparency."

Hopkinson has recently made measurements of the radiation emitted in the course of an explosion in a closed vessel and subsequent cooling. A bolometer made of blackened platinum strip was placed outside a window of fluorite in the walls of the explosion vessel. The electrical resistance of this bolometer was recorded by means of a reflecting galvanometer throwing a spot of light on a revolving drum; and an optical indicator traced simultaneously a record of the pressure on the same drum. He found that the total heat radiated during an explosion of a 15 per cent. mixture of coal gas and air and subsequent cooling, amounted to over 22 per cent. of the whole heat of combustion. The radiation which had been received at the moment of maximum pressure amounted to 3 per cent.; and it continued, although at a diminishing rate, for a long period. Radiation was still perceptible half a second after maximum pressure, when the gas temperature had fallen to 1000° C.

Nature and Origin of the Radiation from Flames.

In the gas-engine cylinder and in explosion experiments, we are usually concerned with flames in which there is some excess of air. A mixture of similar composition burnt at atmospheric pressure would give an almost non-luminous flame; in the gas-engine, there is more luminosity on account of the greater density. There is, however, no reason to suppose that the radiation in the gas-engine cyclinder differs materially as regards its quality or origin from that emitted by an open flame.

A very complete analysis of the radiation from different kinds of flame was made by Julius; and his experiments leave no doubt that the radiation is almost wholly due to the carbonic acid and steam molecules. He examined the spectrum of the flame by means of a rock-salt prism; and he found that in all flames producing both carbonic acid and steam, most of the radiation was concentrated into two bands, the wave-lengths of which are, respectively, 4·4 μ and 2·8 μ. In a pure hydrogen flame, the 4·4 band disappears completely, but the other remains; and in the pure carbonic oxide flame the 2·8 band disappears, the other remaining. These results are independent of the nature of the combustible gas; the spectrum depending solely on the products of combustion.

A confirmation of the statement that the radiation from these flames originates in the carbonic acid and water molecules only, was furnished in the course of the work by R. von Helmholtz, to which reference has been made above. He measured the amount of radiation per litre of gas consumed, as emitted by flames of given size burning, respectively, hydrogen, carbon monoxide, and certain compound gases, such as methane, giving both carbonic acid and steam. The supply of air was adjusted in each case so that the flame was just non-luminous. His results are best given in his own words; but it should be stated that he worked with a small flame about 6 mm. diameter, and measured the radiation with a bolometer, taking the steady change of its resistance as a measure of the amount of radiation falling upon it.

According to the experiments of Julius described in the first chapter, the quality of the radiation of flames depends only on the nature of the burnt, and not on that of the burning, gases. It is relevant to inquire whether the quantity of radiation is also dependent on the mass of the products of combustion. I have calculated in the second and third columns below how many litres of water and carbonic acid respectively arise theoretically from each litre of combustible gas. I then assume that for every litre of water produced as much radiation is sent out as corresponds to the radiating power of a hydrogen flame—for this gas yields 1 litre of water per litre of combustible—and that in a corresponding way the radiation from 1 litre of carbonic acid would be determined by the radiating power of the carbonic oxide flame; and I can then calculate the radiation from the non-luminous flames of methane, ethylene, and coal gas.

Gas.	Litres.		F	
	H_2O.	CO_2.	Observed.	Calculated.
Hydrogen	1	0	74	—
Carbon monoxide .	0	1	177	—
Marsh gas	2	1	327	325
Ethylene	2	2	510	502
Coal gas	1·2	0·5	181	179

The correspondence between the calculated numbers with the radiation from a flame which has just been rendered non-luminous surprised me the more since the latter is conditioned, in some measure, by the volume of air mixed with the gas; and this is very different for the three non-luminous flames. On this account, it cannot be asserted that this agreement is not accidental. Moreover, the number of observations is much too small. Nevertheless, the experiment seems worthy of record, and will be followed up further.

With regard to the last remarks, it is to be noted that the fact that the flame was just rendered non-luminous shows that the air was in each case in approximately the proportion required for complete combustion. The heating value of such a mixture is much the same for all the gases in the above table; and the temperatures of the flames would be still more nearly the same, the higher heating value of a carbonic oxide mixture being partly neutralized by the high specific heat of the products. The agreement is certainly more than a coincidence. W. T. David, from a comparison of the radiation emitted in the steam and carbonic oxide bands respectively in a coal gas and air explosion, infers that carbonic acid radiates about two-and-a-half times as much as steam per unit of volume. This result (obtained in ignorance of Helmholtz's estimate) agrees with it almost exactly.

Cold carbonic acid shows a strong absorption band at the same point of the spectrum as the emission band given by a flame in which carbonic acid is produced; and water-vapour powerfully absorbs the radiation from a hydrogen flame.

As stated above, it is most probable that the radiation in an explosion also consists almost entirely of the same two bands as are emitted by the bunsen flame. A complete analysis of the radiation from an explosion has not been made; but Hopkinson and David found, using a recording bolometer, that the radiation is almost completely stopped by a water-cell, and that it is largely stopped by a glass plate. It follows that the luminosity of the

flame in an explosion or in a gas-engine accounts for but little of the energy which it radiates.

Molecular Theory of Radiation from Gases.

Much difference of opinion exists as to the physical interpretation of the facts described in the preceding sections. The issues in this controversy can conveniently be stated in terms of the molecular theory; and it is, therefore desirable to give a short account of this theory. But it will be apparent that the issues are not merely of theoretical interest, but are in large measure issues of fact capable of being tested by experiment, and that the answers to important practical questions may depend on the manner in which they are settled.

According to the kinetic theory, the energy of a gas must be referred partly to translational motion of the molecules as a whole, and partly to motions of some sort internal to the molecules. The translational motion is that which causes the pressure of the gas; and, in the case of gases for which $\frac{pv}{\theta}$ is constant (with which alone we are concerned in this discussion), the translational energy per unit of volume is equal in absolute measure to one-and-a-half times the pressure. This part of the energy may conveniently be called "pressure energy." It amounts to nearly three calories per gramme-molecule, or to 12 feet-pounds per cubic foot per degree C.

The other part of the energy produces no external physical effect except radiation; and at ordinary temperatures, when there is no radiation, its existence and amount are inferred from the fact that, when work is done or heat put into the gas, the corresponding increase in pressure energy amounts to only a fraction of the whole. The internal motions to which this suppressed energy corresponds may be pictured as of a mechanical nature, such as the vibrations of spring-connected masses, or as rotation about the centre of gravity of the molecule. But there is not the same reason as exists in the case of the transitional energy for supposing they are really of this character. They may be, and, indeed, probably are, electrical phenomena, at any rate in part. Any radiation from the gas must take its origin in this internal motion; and so much of the motion as gives rise to radiation must be of a periodic character, and have a frequency equal to that of the radiation emitted. It will be convenient to call the whole energy which is internal to the molecule "atomic energy," and that part of it which gives rise to radiation may be called "vibrational energy." The vibrational energy may be imagined as due to high frequency vibrations within the molecule, and the rest of the atomic energy as due to slower movements—perhaps rotations of the molecule as a whole—which do not produce any disturbance in the æther. This remaining energy may conveniently be called "rotational;" it being understood that the motion to which it corresponds is not necessarily physical rotation, but is some internal motion which gives no external physical effects.

When the gas is in a steady state, the various kinds of energy will bear definite ratios to one another, dependent on the temperature and pressure. It may be expected, however, that after any sudden change of temperature or pressure, the gas will not at once reach the steady state of equilibrium corresponding to the new conditions. For instance, it may be that, in the rapid compression of a gas, the work done goes at first mainly to increasing the translational energy. If, in such case, the compression be arrested, and if there be no loss of heat, this form of energy will be found in excess; and a certain time, though possibly a very short time, will elapse before the excess is transformed by collisions into atomic energy, and the state of equilibrium attained. This change would be manifest as a fall of temperature or of pressure without any change of energy.

If, on the other hand, the gas be heated by combustion, the first effect is undoubtedly an increase in the energy of those molecules, and of those only, which have been formed as the result of the combustion; and it is probable that in the first instance the energy of the newly-formed molecules is mainly in the atomic form. Before equilibrium can be attained, there must be a process of adjustment, in the course of which the energy of the new molecules will be shared in part with inert molecules—*e.g.*, the nitrogen in an air-gas explosion—while the translational form of energy will increase at the expense of the atomic energy. The final state of equilibrium reached will be the same at the same temperature, whether the gas was heated in the first instance by combustion or by compression. The assumption that this is the case is involved in any statement of volumetric heat as a definite physical quantity. The pressure energy in the final state of equilibrium is certainly shared equally between the different kinds of molecules; but the atomic energy is not necessarily equally shared. It is known, for example, that the steam molecules, after an explosion of hydrogen and air, carry, on the average, more energy than do the nitrogen molecules, though the pressure energy is the same.

The process of attaining equilibrium after an explosion, which has just been described, would (if heat loss were arrested) result in a rise of temperature; and in the ordinary case of rapid cooling it would retard the cooling. It would, therefore, be indistinguishable as regards pressure or temperature effects from continued combustion or after-burning.

Stated in terms of the molecular theory, the first question as to which there is difference of opinion is whether the radiation from a flame arises from gas which is in equilibrium, or whether it comes from molecules which still possess a larger share than they will ultimately (in the equilibrium state) be entitled to, of the atomic energy which resulted from their formation. If the products of combustion of a non-luminous bunsen flame were heated—say, by passing through a hot tube—to the average temperature of the flame (taken to be equal to that of a solid body of moderate extent immersed in it), would they emit substantially the same amount of radiation? In order to clear the ground for the discussion of this question, it will be convenient, first, to state two or three points about which there will probably be general agreement. First, there is here no question of the origin of luminosity, for the luminous part of the radiation from the flame possesses practically no energy. Secondly, the radiation, whether in the heated gas or in the flame, arises almost entirely from the compound constituents carbonic acid and water; in neither case does any come from the molecules of nitrogen or of excess oxygen. And, thirdly, the powerful absorption of cold carbonic acid for the radiation from a carbonic oxide flame, and of water vapour for that from a hydrogen flame, will probably lead all to admit that these gases when heated will emit some radiation of the same type. The only question is, How much?

R. von Helmholtz was of opinion that the radiation in a flame comes mainly from molecules which have only just been formed, and which are, therefore, still in a state of vigorous vibration. Pringsheim, Smithells, and others take the same view. This is practically equivalent to saying that this radiation, like the radiation of higher frequency which gives luminosity, is due to chemical action and not to purely thermal causes. On the other hand, Paschen and some others have maintained that the radiation from a flame is purely thermal, or that it arises from gas which has attained the normal or equilibrium state, and is substantially the same as that which would be emitted if the products of combustion were heated.

It will readily be seen that the difference between the two opinions really turns on the question of the time taken by a gas which is not initially in, or has been disturbed from, the equilibrium state to attain that state. All will concede that the carbonic acid or steam molecule will radiate more powerfully just after its formation than at any other time. If, as R. von Helmholtz contended, the greater part of the radiation which it gives out in the course of its life is to be ascribed to this early period of its history, we must suppose that this period is sufficiently extended to give time for the emission of a considerable amount of energy, with a rate of radiation which, though greater than that of the gas in its ultimate equilibrium state, is at least of the same order of magnitude. In other words, we must suppose that the process which may indifferently be called attainment of equilibrium, or continued chemical action, must go on in the gases as they pass through the flame for a time of the order perhaps of 1-10th of a second. For if it be supposed that equilibrium is reached in an excessively short time (say) in 1-1000th of a second or less, then the radiation, if ascribed to this short period, must be supposed to be of corresponding intensity—there must be a sudden and violent flow of energy by radiation just while combustion is going on, and very little radiation after it is complete. This is, however, negatived by the bolometer measurements made during an explosion, which show that radiation goes on for something like half a second after maximum pressure [see Appendix B]. Those who hold that the radiation emitted by carbonic acid and steam is mainly due to continued combustion, must be prepared to admit that such combustion goes on for a long period after the attainment of maximum pressure in an explosion. The issue involved here is, in fact, the same as that in the controversy about "after-burning."

The principal argument advanced by R. von Helmholtz in support of his view is the experimental fact discovered by him, that the radiation of a flame is diminished by heating the gas and air before they enter the burner, in spite of the fact that the temperature of the flame must be raised. This he explains by the acceleration of the approach to the state of equilibrium which would be brought about by the more frequent collisions between the newly-formed compound molecules and their neighbours.

The question of the velocity with which a gas approaches its normal state after a disturbance, has been much discussed in connection with the kinetic theory. Immediately after an explosion, we have an extreme case of such a disturbance; the atomic energy being, at any point which the flame has just reached, in considerable excess. The transformation of this energy into the pressure form will proceed at a rate diminishing with the amount remaining to be transformed, and, in the final stages of the process at all events, proportional thereto. The slowness of approach to the state of equilibrium may be measured by the time required for the reduction of the untransformed energy in any specified ratio. It is usual to take $\frac{1}{e}$ as this ratio; and, following Maxwell, the corresponding time may be called the "time of relaxation." Estimates of this time, based on the kinetic theory of gases, may be made in various ways; but they all involve hypotheses as to the nature of the action between the molecules, and must be regarded as little more than speculation. It will be well, however, to indicate the general character of the arguments on which they are based. By methods which need not be considered in detail here, it is possible to calculate the number of collisions with its neighbours which the average molecule undergoes per second. This calculation can be approached in various ways, based on different kinds of data. But they all lead to the same result, at any rate as regards order of magnitude—namely, that a molecule of air at normal temperature and pressure collides on the

average 3 × 10 times per second with other molecules. At every collision, the energy that is distribution in the colliding molecules is modified, both as regards the manner in which it is shared between the two and the relative proportions due to vibration and translation in either. It is argued that, after every molecule has suffered a few thousand collisions, which will happen in a millionth of a second, the gas must have reached a steady average state. This argument would, however, be upset if the interchange of energy as between vibration and translation at each collision were sufficiently small. It is only necessary to suppose that a vibrating molecule loses less than one thousand millionth part of its vibrating energy at each collision, to raise the time of relaxation to something of the order of a second. Any objection to this supposition must be founded on some hypothesis, which cannot be other than entirely speculative, as to the mechanism of a collision. The kinetic theory, therefore, can give no information about the absolute value of the time of relaxation, though it provides valuable suggestions as to the way in which that time is affected by the temperature and the density of the gas.

There is plenty of physical evidence, however, that under ordinary circumstances the time of relaxation is excessively short. The phenomena of the propagation of sound show that compressions and rarefactions of atmospheric air may take place many thousands of times in a second without the gas departing appreciably at any instant from the state of equilibrium. The experiments of Tyndall, in which an intermittent beam of radiant energy directed through the gas caused variations of pressure sufficiently rapid to give sounds, show that the transformation of vibrational into pressure energy under the conditions of his experiments is a process far more rapid than any with which we are accustomed to deal in the gas-engine or in the study of gaseous explosions. The departure from equilibrium which follows combustion is, however, of a special kind; and it may be that the gas is slower in recovering from it than when the disturbance is that produced by propagation of sound at ordinary temperatures.

Transparency.

The radiation from hot gas is complicated by the fact that the gas is to a considerable extent transparent to its own radiation. The radiation emitted, therefore, depends upon the thickness of the layer of gas, instead of being purely a surface phenomenon, as in the case of a solid body. This property, besides being of great physical interest, is important from the point of view of the Committee, because upon it depends, or may depend, the relative magnitude of radiation losses in engines or explosion-vessels of different sizes.

The transparency of flames is well illustrated by some experiments which Professor Callendar has been making, and which he showed to the Committee. The radiation from a Mêker burner (which gives a "solid" flame without inner cone) was measured by means of a Féry pyrometer, the reading of which gives a measure of the radiation transmitted through a small cone intersecting the flame and having its vertex at this point of observation (see fig. 1). Callendar proposes to give the name "intrinsic

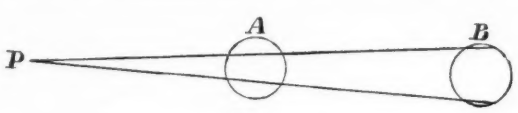


Fig. 1.

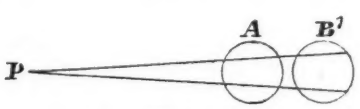


Fig. 2.

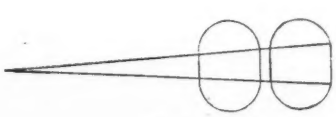


Fig. 3.

radiance" to the radiation of a flame measured in this way, divided by the solid angle of the cone. When a second similar flame was placed behind the first in the line of sight, it was found that the reading recorded by the pyrometer was considerably increased, but not doubled. The first flame appeared to be partly, but not completely, transparent to the radiation emitted by the second. A third flame placed behind the first two contributed a further but smaller addition to the radiation; and as the number of flames in the row was increased, the radiation received from each fell off according to an exponential law. The total radiation from the whole row (which is that recorded on the pyrometer) tends to a finite limit as the number of the flames is increased. The radiation from a depth of 12 cms. is about half, and that from a depth of 100 cms. is within half per cent. of that emitted by an infinitely great depth.

The general result of Callendar's experiments is to show that flames of a diameter of 3 cm. or less burning at atmospheric pressure emit radiation approximately in proportion to the volume. If the diameter be increased beyond that figure, the radiation will also increase, but not in proportion to the volume of the flame. Radiation from very large flames would tend to become proportional to the surface; but no certain inference as to the diameter of flame for which this would be substantially true can be drawn from Callendar's experiments, because he was looking along a thin row of flames with but little lateral extension.

The flames met with in a gas-engine cylinder or in explosion vessels differ from open flames such as can readily be produced in the laboratory, both in respect of the lateral extension which has just been mentioned, and also in respect of density. In both these particulars, the difference is rather great; the least dimension of the mass of flame in a gas-engine cylinder being only in the smallest sizes comparable with the diameter of the Mêker burner flame, while the density of the gas just after firing in the gas-engine is from twenty to thirty times that of the burner flame gases. It does not seem possible from theoretical considerations to determine the effect of these two factors with sufficient accuracy to enable any quantitative inference as to radiation in the gas-engine to be drawn from laboratory experiments on flames; but it is useful to discuss their probable qualitative effects.

In fig. 1, P is the point of observation at which the pyrometer is placed, as in Callendar's experiments; and the portion of the flame from which the radiation is measured is that intercepted by the small cone. If a second similar flame B is placed behind A at a considerable distance, but so that it is intersected by the cone, then the radiation recorded by the pyrometer will be increased (say) by 50 per cent., showing that of the radiation emitted by B and falling on A 50 per cent. is absorbed, and the remainder is transmitted to the pyrometer. The absorbed energy is, of course, not lost, but must result in slightly increased radiation from A in all directions. The flame A appears to be a little hotter because of the proximity of B. Thus the increase of radiation absorbed at the pyrometer is due, not only to the radiation transmitted from B, but also to an increase in the intrinsic radiance of A. If the two flames are a considerable distance apart, the latter part is negligibly small, since the flame A does not then receive much radiation from B, and what it does receive is dissipated in every direction. But when flame B is pushed close up to A into the position of B^1 (fig. 2), this effect may be considerable; and it is obvious that it will be greatly enhanced if the two flames are extended laterally, as in fig. 3. For in such case, flame A must get rid of the energy which it is receiving by radiation from B^1 mainly by an enhanced radiation in the direction of P. It may, therefore, be expected that the effect of lateral extension will be to make the flame apparently more transparent.

To a first approximation it may be expected that the radiating and absorptive powers of a gas at a given temperature will be proportional to its density. That is to say, two geometrically similar masses of flame, in which the temperatures at corresponding points are the same, and the densities in inverse proportion to the volumes (so that the total masses are the same), will radiate in the same way, and to the same total amount. It would seem that this must be so, so long as the vibrations of the radiating molecules are the same in character and amplitude in the two cases. For there will then be the same number of molecules vibrating in exactly the same way and arranged in the same way, in the two cases. The only difference is in the scale of the arrangement; and this can only affect the matter if the distance between the molecules is comparable with the wave-lengths of the radiation emitted, which is not the case. It is only, however, within moderate limits that the molecular vibrations are independent of density. Angström found that the absorption of the radiation from a given source in a tube of carbonic acid at ordinary temperature and at atmospheric pressure was reduced by increasing the length and diminishing the pressure in the same proportion so as to keep the mass of gas constant. Schäfer found that, on increasing the pressure, the absorption bands of this gas were widened, so that the curve connecting intensity of radiation and wave-length did not remain of the same shape. These experiments were made at low temperatures; and at the higher temperatures in which the Committee are more particularly interested there has been but little work. There is no reason to doubt, however, that the character and amount of the radiation from carbonic acid and steam at high temperatures will change with the density.

From the point of view of the molecular theory, such a change might be anticipated from either of two causes. An increase of density implies a proportionate increase in the frequency of molecular collisions; and this would result in greater facility of interchange between the translational and atomic types of energy. It is possible that the equilibrium proportion of the two types might be different in consequence. The denser gas may conceivably possess, with a given amount of translational energy, more atomic energy, and therefore radiate more strongly at a given temperature. It is certain that there would be a more rapid attainment of equilibrium in the gas after an explosion or a rapid expansion. Another possible cause is a direct interaction between the molecules apart from collisions. Two molecules at a sufficient distance apart will vibrate practically independently—each behaving as though the other was not there—except that there will be a tendency for them to vibrate in the same phase. But if the two are close together, they react on one another, so that the natural period or periods of the two together will not be the same as those which each would have if it were isolated.

Such direct measurements as have been made of the radiation after a closed vessel explosion suggest that the flame is more transparent than might be inferred from the experiments on open flames. According to information given to the Committee by Professor Hopkinson, W. T. David has found that the radiation received by a bolometer outside a fluorite window in the cover of a cylindrical explosion vessel 30 cm. by 30 cm. is greatly increased by highly polishing the portion of the opposite cover which can be "seen" by the bolometer. This implies that a thickness of 30 cm. of flame, under these circumstances, can transmit much of the radiation which it emits. The density of the gas in this case was atmospheric; and the 30 cm. thickness in the explosion vessel would be equivalent to perhaps 150 cm. of open flame, if absorption were simply proportional to density. According to Callendar's experiment, such a thickness would be almost completely opaque. It is possible that the lateral extension is sufficient to account for this result. The open flame should be a cylindrical mass of dimensions 150 cm. by 150 cm., instead of a long strip with a cross section of 3 cm., in order to make the two cases strictly comparable. It will be remembered that, in the discussion above, it appeared that the laterally extended flame would seem to be more transparent.

Appendix A.

Radiation from Flames.

By H. L. Callendar.

In the course of my experiments in 1903-4 with a small petrol motor of 2·36-inch bore, on the variation of efficiency with speed, I became convinced that the greater part of the loss of efficiency with a small high-speed motor was practically independent of the speed. Loss by radiation from the flame appeared to be one among the many possible causes contributing to this result; and I accordingly made some experiments on radiation from flames, with a view to estimate the probable order of magnitude and the possible limits of the loss incurred. The experiments were necessarily of a qualitative character, and could not be directly applied to the calculation of the actual loss occurring in an internal combustion engine; but they appeared to indicate that the effect was much larger than had generally been supposed, and could not be neglected in a discussion of the heat loss occurring in a gaseous explosion. Some of the results of these experiments were mentioned in the discussion on a paper by Professor B. Hopkinson, "Explosions of Coal Gas and Air," and a general summary was given in the discussion on my paper, "On the Effect of Size on the Thermal Efficiency of Motors," from which the following is a quotation:

> A large part of the energy of the flame during ignition exists in the form of energy of vibration of the dissociated and recombining ions, which is proved by the fact that a flame radiates energy more intensely than a mass of inert gas at the same temperature. The energy of vibration is realized as pressure, or energy of translation, only in proportion as the ions combine and equilibrium is established. The loss of thermal efficiency from this cause is merely another aspect of dissociation or increase of apparent specific heat, and is not a loss of heat at all, though it gives rise, as already explained, to a considerable diminution of the thermal efficiency. But while the condition of flame persists, there is necessarily some loss of heat by radiation to the walls. In order to estimate this loss, I made a series of direct measurements of the actual proportion of the heat or combustion radiated from various flames—luminous and non-luminous—some of which were quoted by Hopkinson in his paper. I found that the heat radiated from an ordinary non-luminous bunsen flame might amount to 15 or 20 per cent., but that it depended on the duration of the incandescence and was much smaller (corresponding with a reduction in the size of the flame) in explosive mixtures. It is not possible to estimate separately the exact amount of this loss in the cylinder of a gas-engine; but I think it belongs chiefly to losses of the type A being proportional to the wall-surface exposed, and practically independent of the time, since the duration of the flame is short in the most efficient mixtures. It is probable, however, that part of the radiation loss taking place during the propagation of the flame and throughout its mass is proportional to the volume and not to the surface, in which case it would be represented by a constant term in the expression for the loss of thermal efficiency.

The only account which I have been able to find of previous systematic experiments on the proportion of the heat of combustion radiated from a flame, is in a thesis for doctorate by Robert (the son of Hermann) von Helmholtz. For a majority of non-luminous hydrocarbon flames mixed with air, R. Hemlholtz finds approximately the same result—namely 5 per cent. of the heat of combustion radiated. According to my experiments this low value is to be explained by the fact that he employed in these measurements small flames (6 mm. diameter by 60 mm. high), which were probably burning at a comparatively low temperature, and which do, as a matter of fact, give a percentage of this order. In one case, he finds 8·7 per cent. of the heat of combustion radiated by a flame 11·8 mm. diameter.

In my own experiments the heat radiated from flames of various sizes and burning under different conditions, was measured (in calories per square cm. per minute) at a measured distance, by means of an Angström pyrheliometer in a special mounting. The constant of the pyrheliometer, which had shown signs of change, was checked by means of a radio-calorimeter and also by an absolute measuring bolometer. An ordinary wet-meter was employed for measuring the gas supply to the flame; and the same meter was employed in the measurement of the calorific value of the gas with a Boys calorimeter. In some experiments the air supplied to the flame before ignition was measured with the apparatus subsequently employed by Swann in his experiments on the specific heat of air and carbonic acid. This was useful for estimating the strength of the mixture in relation to the appearance of the flame, and for varying the temperature, but could not give quite exact results, because the flames were necessarily burning in free air. With the air and gas adjusted as nearly as could be estimated in the proportions required for complete combustion, the proportion of heat radiated varied from 10 to 15 per cent. for burners from 1 inch to 4 inches in diameter. As the air supply was reduced for the same rate of gas consumption, the size of the flame increased and also the heat radiated. A maximum of 15 to 20 per cent. was reached for these burners when a brilliant and well-defined inner cone was formed. If the amount of air supplied was in excess of that required for complete combustion, the radiation fell off considerably, in consequence of the reduction in size and fall in temperature of the flame. When the air supply was reduced until the inner cone disappeared, with burners of this type, the flame became unsteady and was reduced in temperature; the radiation falling to about 12 to 16 per cent. With steady luminous flames, of the argand or batswing type, there was a considerable increase of radiation on excluding air from the flame. With small flames of low temperature, the proportion of heat radiated might be as low as 2 or 3 per cent.

These results appeared to indicate that the radiation depended largely on the size of the flame as well as on the temperature, and on the presence of carbonic oxide or solid carbon when the air was insufficient for complete combustion. The mixtures employed corresponded fairly with the range available in a petrol motor; but the temperature of the flame in a motor, with ignition at constant volume, would certainly be much higher. A considerable percentage of the loss of thermal efficiency in such cases might evidently be ascribed to radiation. The exact proportion could not be directly estimated; but it occurred to me, in preparing this note, that the probable effect of radiation on the variation of efficiency with size could be deduced by a more complete study of one particular type of flame, and by measuring the radiation and the absorption for different thicknesses. With the assistance of Mr. G. Nelson, I accordingly repeated and extended some of these observations.

Experiments with a Méker Burner.

The type of burner selected for these experiments was the Méker burner, with a nickel grid of 3 cms. diameter, consuming gas at the rate of 0·185 cubic foot per minute. The heat radiated was measured, in calories per square cm. per minute, by an Angström pyrheliometer at a distance of 52 cms.; and the result was multiplied by 4522 to deduce the total radiation in calories per minute, assuming the flame to radiate equally in all directions. The lower calorific value of the gas was measured wet under the temperature and pressure of the experiment, and was found to vary from 470 to 500 B.Th.U. per cubic foot. With full air supply (the gas and air being nearly in the proportions required for complete combustion), the burner gives a solid homogeneous conical pointed flame, with no indications of an inner cone. As the air supply is reduced, minute cones make their appearance over the grid, and finally coalesce into a single steady brilliant inner cone, which increases in size. The percentage of heat radiated rises steadily with the increase of size of the flame—from 10·5 with a full air supply to 16 per cent. as a maximum with a large and bright inner cone. Beyond this point the inner cone becomes ill-defined; the flame flickers; and the radiation falls off to 14 per cent.—rising again to over 16 per cent. as the flame becomes luminous. These variations are compared in the accompanying table with the approximate composition in volumes of air to one of gas before ignition. The form of the curve depends to some extent on the shape, size, and nature of the flame. It would not be the same for a batswing or argand flame. The rate of gas consumption was maintained approximately constant, and the size of the flame varied with the strength of mixture.

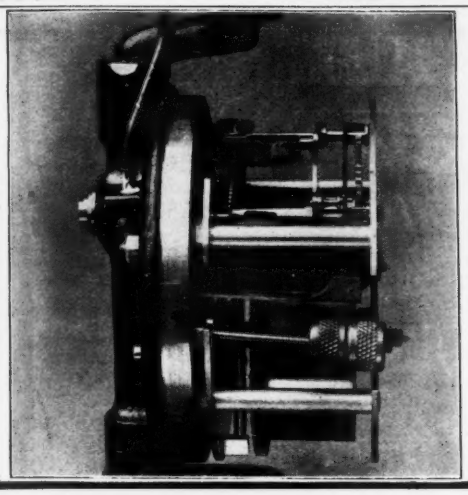
The total radiation of Méker burner per cent. of heat of combustion was:—

Total radiation per cent. .	10·5	12·3	14·0	15·9	14·1	14·6	17
Ratio air gas by volume . .	5	4	3	2·5	1·5	1	0

The gas was in all cases completely burnt. The ratio of air to gas before ignition merely describes the nature of the flame. Mixtures in these proportions, if burnt without any further addition of air, would not, of course, radiate the same percentage of heat. With the ratio air to gas = 5, the duration of the luminous flame was estimated at about 1-50th of a second.

Intrinsic Radiance of Flame.

The intrinsic radiance of a flame has the same meaning in respect of total energy of radiation that intrinsic brilliance or brightness has in respect of luminosity. It may be measured by the radiation emitted per unit area of surface; but in the case of a flame which is more or less transparent, the radiation comes from a finite thickness, and must be measured per unit of solid angle subtended. This measurement may conveniently be effected by means of a total radiation pyrometer of any kind, in which an image of the flame is formed on a radiometer or bolometer. A Féry mirror pyrometer was used for this purpose; the instrument being focussed on the flame at a height of 4 to 5 cms. above the grid, where the flame was steady and sensibly homogeneous.



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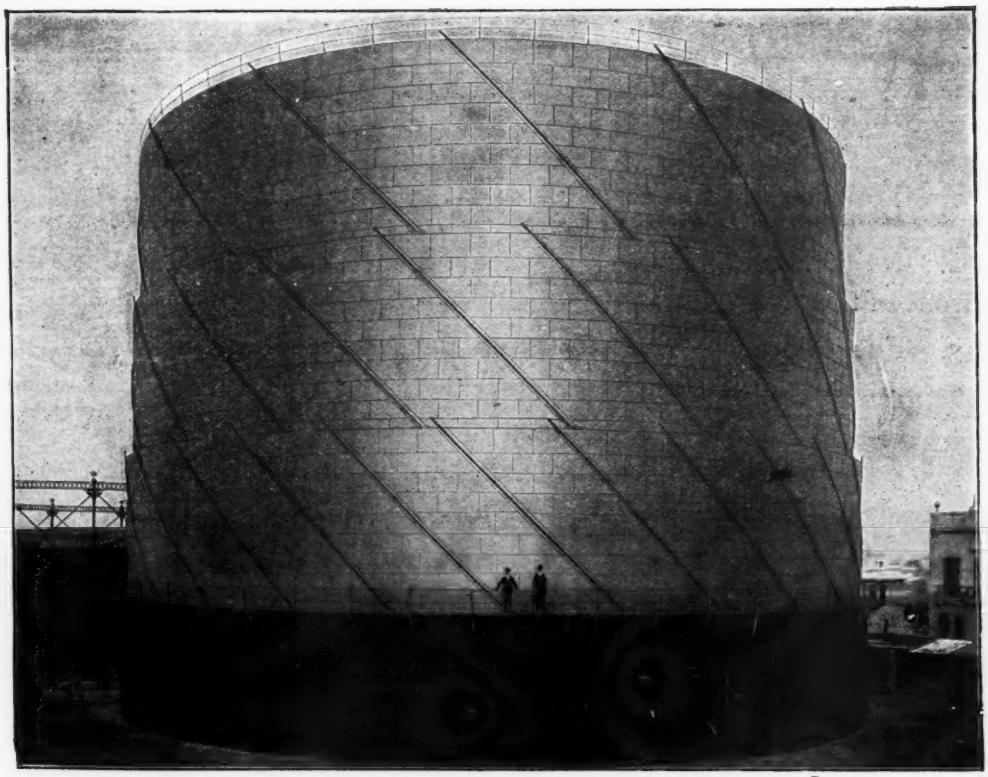

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With this restriction, it was found that the intrinsic radiance of the Méker burner did not vary materially as the air supply was reduced from that necessary for complete combustion, until the inner cone became so large that the flame could no longer be regarded as sensibly homogeneous. This showed that the increase of total radiation simultaneously observed was due chiefly to the increase in the size of the flame, and that the increase of thickness of the flame was compensated either by a fall in temperature or by an increase in absorptive power. The thickness of the flame at the height focussed in the pyrometer varied from 2·8 cms. with a full air supply to 3·6 cms. when the inner cone was 3 cms. high and just cleared the area focussed.

In order to determine the manner in which the intrinsic radiance R varied with the thickness x of the flame in the line of sight, and to measure the co-efficient of absorption, six precisely similar burners were mounted in a row along the axis of the radiation pyrometer, which was focussed in such a way that the reading was the same for any one of the burners singly or for any combination of the same number of burners at different distances. The pressure of the gas supply was regulated to a constant value, and care was taken to prevent the air in the laboratory becoming contaminated, which produced a notable effect on the radiation. Several series of measurements were taken with one to six burners lighted in different orders, for two distinct states of the flame which were easily reproducible—(1) with full air supply, (2) with the inner cones 2·5 cms. high. In the latter case the flames all touched each other, and the layer of flame was 21·6 cms. thick and was sensibly homogeneous.

Summary of Observations.

1. Full air supply, mean thickness per flame, 2·8 cms.

Number of flames	1	2	3	4	5	6
Radiation observed	68	124	171	214	250	282
Radiation calculated	66	124	173	216	250	282

Formula $R = 473\ (1 - e^{-\cdot0537x})$.
Limit R/x when $x = o$, $= 473 \times \cdot0537 = 25\cdot4$ per cm. thickness x.
Limit of R when $x =$ infinity, $R = 473$.

2. Cones 2·5 cms. high. Mean thickness per flame, 3·6 cms.

Number of flames	1	2	3	4	5	6
Radiation observed	72	122	165	197	232	261
Radiation calculated	66	120	166	201	232	257

Formula $R = 373\ (1 - e^{-\cdot0541x})$.
Limit R/x when $x = o$, $= 373 \times \cdot0541 = 20\cdot2$ per cm. thickness.
Limit of R when $x =$ infinity, $R = 373$.

The observed and calculated values agree as closely as could be expected with the exponential law of absorption, which is fairly appropriate in this case, since the radiation emitted is necessarily of the same quality as that absorbed, and the flame is nearly homogeneous. An apparent confirmation of the formula is that the coefficient of absorption is practically the same—namely 0·054 for the two flames. The limit of R/x, when $x = o$, which gives the intrinsic radiance per cm. of flame corrected for absorption, is higher for the case of complete combustion because the temperature of the flame is higher. The limit of radiance for an infinite thickness of flame is higher in the same proportion. The radiation observed for a single flame in case (2) is rather larger than that calculated, because the thickness of a single flame was slightly greater than the mean of several flames in contact. It will be observed that the flame is surprisingly transparent to its own radiation.

It is very commonly assumed that, because a flame absorbs precisely those radiations which it emits, and absorbs them in the same proportion as it emits them, the flame would, therefore, be practically opaque to its own radiation; so that the radiation proceeding from the interior of a mass of homogeneous flame might be neglected, and the total radiation assumed proportional to the surface. The above observations show that this is very far from being the case, owing to the relatively wide separation of the radiating and absorbing molecules.

Effect of Temperature and Pressure.

The effect of temperature and pressure on the intrinsic radiance of a flame of this kind can be theoretically predicted with a reasonable degree of probability; but it would be difficult to determine either experimentally. Within quite moderate limits of pressure, the radiating and absorbing powers of a flame per unit thickness at a given temperatnre and composition should both vary directly as the pressure or density. The value of the radiation from a layer of thickness 1 cm. at a pressure of 10 atmospheres would be the same as that from a layer of 10 cms. at 1 atmosphere, assuming that the quality of the radiation or the nature of the combustion were not altered by the pressure. This effect is represented by increasing the absorption coefficient in proportion to the pressure, leaving the limit for infinite thickness unaltered.

The effect of temperature is more difficult to estimate because the radiation from a flame is very complicated, and there are no means of accurately measuring the temperature. Nernst, from observations by others on the cooling of an explosive gas mixture, maximum pressure about 6 atmospheres, allowing for convection and conduction, finds the radiation to vary as the fourth power of the temperature. The method is very uncertain; and his conclusion was most severely criticized by Lummer, Bringsheim, and Schaefer, who explained that the radiation was quite different from that of a black body, and that the quality of the radiation was little, if at all, affected by pressure up to 4 atmospheres.

The principal maxima of emission and absorption in the bunsen-flame spectrum are at 2·8 μ and 4·4 μ. Taking a mean wave-length of 3·5 μ, it is easy to estimate how the intensity should vary with temperature by assuming Planck's equation. The following table gives approximate relative values for comparison with the fourth-power law of Stefan for the radiation of a black body:

Absolute temperature	1000°	1500°	2000°	2500°	3000°
Radiation—					
Planck	·016	·059	·142	·233	·331
Stefan	·009	·045	·142	·347	·721

The rate of variation, according to Planck's formula for a single wave-length, is much slower than the fourth-power law, and tends in the limit to be directly proportional to the absolute temperature at high temperatures. The actual rate of variation should lie between these limits, but nearer to Planck, unless carbon begins to separate in rich mixtures at high temperatures.

Effect of Radiation Loss on Thermal Efficiency.

Although it is not possible to calculate the absolute magnitude of the radiation-loss in a motor, or to deduce from it the relative loss of thermal efficiency, it is not difficult to see in what manner this loss should vary with flame temperature and with linear dimensions of the cylinder. We may assume for this purpose that the cylinder at the moment of maximum pressure is filled with practically homogeneous flame and that the walls are practically non-reflecting. For similar motors under similar conditions the heat-loss per explosion will vary as the product RS of the intrinsic radiance R and the surface S. The percentage heat-loss should vary as RS/V, where V is the volume of the cylinder. This will vary as R/D, where D is the diameter, for similar motors. Assuming a pressure of 20 atmospheres in a cylinder of 2 inches (5 cms.) diameter, the equivalent thickness of flame at 1 atmosphere is 100 cms., and the intrinsic radiance for a flame of this thickness has already reached within less than $\frac{1}{2}$ per cent. of its limit for an infinite thickness. The percentage loss due to radiation per stroke will, therefore, vary inversely as the diameter in similar motors; since R will be practically independent of the dimensions in all cases which occur in practice. Since the rate of loss due to radiation diminishes very rapidly with the time, the effect of variation in speed on the radiation loss may be appropriately represented by a factor of the type $(A + Bn)$, where n is the speed in revolutions per minute, as suggested in my paper already quoted at the beginning of this note. From the rapidity of the radiation-loss during ignition, it is clear that the A term will be of considerable importance and will affect the comparison of similar motors of different sizes when running at the same piston-speed (n inversely as D) in the manner explained in my paper. I was convinced on general principles that this would turn out to be the case; but without actually measuring the absorption coefficient it was not possible to assert definitely that R would be practically independent of the dimensions.

The variation of the coefficients A and B with flame temperature will be proportional to R, and will be of the nature already indicated. This is corroborated by my analysis of Dr. Watson's observations in a contribution to the discussion on his paper.

Absolute Value of Intrinsic Radiance.

The absolute value of the intrinsic radiance of these flames was determined by comparison with the radiation of a black body with the same pyrometer. The black body temperature for six flames with full air supply, giving a deflection of 282 scale divisions with the galvanometer, was 679° C. or 952° absolute, for a thickness of 16·8 cms. This means that the intrinsic radiance of such a layer of flame is the same as that of a black body at 67·9° C.

Assuming the radiation from a black body at a temperature θ abs. to vary as $E\,\theta^4$ where E is the radiation constant, and has the value $5\cdot32 \times 10^{-5}$ ergs per sq. cm. per second, or $1\cdot273 \times 10^{-12}$ gm. cals. per sq. cm. per second, the radiation from a black body at 952° abs. or 679° C. would be 63 cals. per sq. cm. per minute.

The limiting value of the intrinsic radiance for infinite thickness would be 105 cals. per sq. cm. per min. in case No. (1) with full air supply, and 83 cals. per sq. cm. in case No. (2) with cones 2·5 cms. high. These values would correspond approximately with the initial rates of loss of heat by radiation per sq. cm. of surface in a gas-engine cylinder filled with similar flames at corresponding temperatures. The higher value gives a loss of 175 cal. per sq. cm. in the first tenth of a second. Professor Hopkinson's experiments with a bolometer placed outside an explosion vessel, in which the flame temperature was certainly a good deal higher, give ·315 cal. per sq. cm. lost in the first tenth of a second after ignition commences, or ·35 cal. in the first tenth after maximum pressure. These are quantities of the same order of magnitude, and differ in the right direction from the value that was deduced above. They may be regarded as confirming the validity of both methods of estimating the absolute value of the radiation loss.

In applying these results to an internal combustion engine, it must be remembered that the radiation is not, in fact, strictly homogeneous. There are considerable variations of temperature, which affect the quality of the radiation. It appears probable that luminous carbon, giving a continuous spectrum, may separate in rich mixtures, more especially if not perfectly uniform, These variations would tend to increase the effective transparency of the flame, and the increase of radiation-loss with dimensions. Some further investigation will, doubtless, elucidate

these points. But, in so far as the flame tends to absorb its own radiation selectively, the theory above sketched may serve a useful purpose as a first approximation.

APPENDIX B.

On Radiation in a Gaseous Explosion.

By B. HOPKINSON.

In the first report of the "British Association Committee on Gaseous Explosions," attention was drawn to the probable importance of radiation in determining the rate of cooling of the mass of hot gas produced by igniting an inflammable mixture in a closed vessel. In the second report reference was made to some experiments which I had made on the effect of coating the walls of the explosion vessel with bright tin-foil. It was found that if a mixture of coal-gas and air of given composition were exploded in a vessel thus lined, the maximum pressure reached was the same (within 1 per cent.) as that given by an identical mixture when the tin-foil lining was blackened; but the rate of cooling was decidedly less. An experiment was also described, in which an attempt was made to measure the actual heat absorption of the walls and the radiation, by means of a bolometer of copper strip, whose temperature was recorded photographically during the progress of the explosion and of cooling—the strip being in different experiments blackened, polished, and placed behind a gas-tight screen of rock salt. A considerable difference was found between the blackened and polished surfaces in respect of heat absorption, and this difference was of the same order as the heat absorbed by the bolometer behind the rock-salt screen. The results were strong evidence that the effect of the tin-foil lining on the rate of cooling was due to radiation, and gave an indication of its order of magnitude. But, as tin-foil is not a very good reflector, and as the rock-salt plate was destroyed by the explosion so that only a single experiment with it was possible, I have thought it desirable to do some further work in the same direction.

I have accordingly had prepared a cylindrical cast-iron explosion vessel, 30 cms. long by 30 cms. diameter, the whole of the interior surface of which is plated with silver; and I have compared the results of exploding a mixture containing 15 per cent. of Cambridge coal-gas—first with the vessel polished as highly as possible, and second with the surface blackened over. All precautions were taken to ensure that the mixture in the comparison experiments should be of identical composition. The pressures were recorded in the usual way—sometimes with a pencil indicator, and sometimes with an optical indicator—the same instrument being used, however, in each set of comparison experiments.

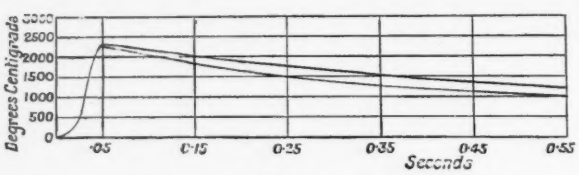


Fig. 4.

Fig. 4 shows superposed the pressure records obtained by the optical indicator in one such comparison. As in the case of the tin-foil lining, there is a difference in the rate of cooling; but the difference is here very much greater—more than twice as great. Further, there is undoubtedly a difference in maximum pressure amounting to between 2 lbs. and 3 lbs. per square inch, which is equivalent to about 60° C. in temperature; or, having regard to the higher volumetric heat in the neighbourhood of 2000° C., to perhaps 5 per cent. in thermal energy.

Comparing the two records it will be seen that when the walls are reflecting, the gas takes about one-and-a-half times as long to reach a temperature of 1500° C. as it does when the walls are blackened. The actual heat given to the walls in the two cases must be the same; so that the mean rate of cooling during this period in the one case is about one-and-a-half times as great as in the other. This proportion remains fairly constant until the temperature has fallen to about 1000° C., when it shows some tendency to diminish. It was found that the precise state of polish of the silver had a great effect on this result—differences in polish hardly appreciable to the eye causing a substantial change in the rate of cooling. In the diagram shown the surface was polished by means of a motor-driven buffing-wheel with rouge, and washed with methylated spirit, and then again polished with a leather.

A number of experiments have also been made with a recording bolometer of silver strip, which was sometimes polished and sometimes blackened. Simultaneous records were taken of the gas-pressure and of the temperature of the bolometer. Two such records, in which the pressure curves are identical, are shown superposed in fig. 5. The bolometer was mounted on a linoleum backing, and there is considerable loss of heat to this backing, which makes the estimate of the absolute amount of heat absorbed rather uncertain. Since, however, the curves of temperature-rise in the two cases (the blackened and the polished) are very nearly similar, differing only as regards temperature scale, the proportion of heat lost will be the same in the two cases, and the ratio of heat absorption by the blackened and polished surfaces will be nearly equal to the ratio of the temperatures. The ratio of the temperatures shown in fig. 5 is 0·75 at the end of 0·25 second from ignition, which agrees as well as might be expected with the ratio of the rates of cooling deduced from the pressure records with blackened and reflected walls—having regard to the great effect of small differences in polish upon the rate of cooling. The ratio of the bolometer temperature increases a little as the gas temperature falls, which again agrees with the gradual approximation as regards rate of cooling disclosed by the pressure records.

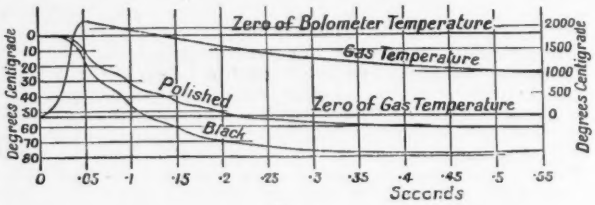


Fig. 5.

Some estimate of the heat lost to the backing can be made as follows: If the temperature of the surface of a solid be caused to vary in a given manner, then the quantity of heat which has passed into it at any time can be calculated by means of the Fourier analysis, provided that the product of the thermal conductivity k and the thermal capacity c of the solid is known—being, for a given temperature variation, proportional to the square root of this product. In the present case the solid is the linoleum backing, and the surface temperature is that of the silver in contact with it, and is given by the bolometer record. The total heat absorbed by the bolometer per square centimetre at any instant can, therefore, be estimated from the bolometer record, subject only to a knowledge of $\sqrt{k\,c}$ which occurs as a multiplier. Thence, assuming that the average heat loss over the whole surface is the same as that absorbed by the bolometer, the whole heat given by the gas can be calculated. This heat loss can be obtained also from the pressure record by deducting from the whole heat of combustion the quantity of heat remaining in the gas, whose energy at a temperature of (say) 1000° C. may be considered as known sufficiently nearly for this purpose. The value of the factor $\sqrt{k\,c}$ is then so chosen as to make the heat obtained from the bolometer equal to that deduced from the pressure record. The following table showing the absolute heat losses has been obtained in this way:

TABLE I.

Time	Temperatures °C.			Heat in Silver Cals. per sq. cm.		Proportion Lost to Backing.		Total Absorption.		Difference b'tween Blackened and Polishd.
	Gas.	Silver.								
		B.	P.	B.	P.	B.	P.	B.	P.	
·05	2150	15·9	12·0	·188	·142	·30	·30	·245	·185	·06
·10	1940	45·8	31·9	·530	·376	·50	·50	·795	·565	·23
·15	1750	61·0	44·1	·720	·520	·70	·69	1·22	·88	·34
·20	1590	70·0	51·7	·826	·610	·90	·88	1·57	1·15	·42
·30	1350	76·8	59·0	·906	·696	1·22	1·18	2·01	1·52	·49
·50	1030	78·7	62·5	·929	·737	1·70	1·63	2·51	1·94	·57

The difference between the loss to the polished and blackened surfaces represents the greater part of the radiation from the gas. There is reason to suppose, however, that it does not represent the whole, because it is probable that at an early stage in the cooling with the polished walls the bright surface of the silver is dimmed by a deposit of moisture.*

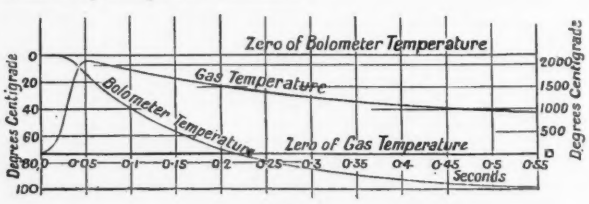


Fig. 6.

Finally, a series of records have been taken with a bolometer placed outside the explosion vessel altogether, but exposed to the radiation of the flame through a window of fluorite (fig. 7). This bolometer was of platinum, blackened with lamp-black; and the records were taken in exactly the same way as in the other cases. A facsimile of one such record is given in fig. 6, and Table II. shows the amounts of heat absorbed by this bolometer at different times. There cannot be any question that the whole of the heat recorded by the bolometer is radiated heat; and I do not think

* The possible importance of such a deposit was suggested to me by Mr. W. T. David, who carried out all the experiments described in this note.

TABLE II.

Time from Ignition.	Temperature °C.		Heat in Platinum Cals. per sq. cm.	Loss by Radiation, &c.	Total Absorbed. Cals. sq. cm.	Heat Absorbed as Percentage of Heat of Combustion.
	Gas.	Platinum.				
·05	2090	13·6	·11		·11	3
·1	1870	39·6	·315		·315	8·5
·15	1690	57·4	·46		·46	12·5
·20	1510	70·3	·57		·57	15·5
·3	1290	84·2	·675	·025	·70	19
·4	1110	91·7	·735	·035	·77	21
·5	980	96·4	·770	·05	·82	22

that there is much doubt that, subject to any reflection from the surface of the platinum (which has not been allowed for), the above figures represent the amount of radiation coming through the fluorite window. Fluorite is said to absorb about 5 per cent. of the radiation falling upon it; but no allowance has been made

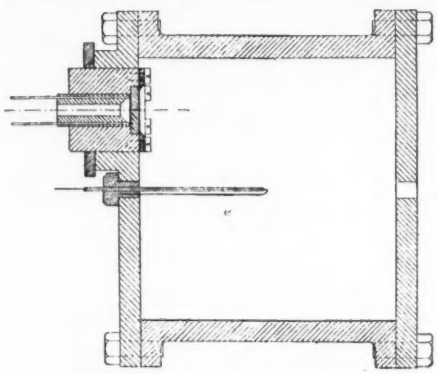


Fig. 7.

for this. It will be seen that the radiation here recorded exceeds by about 50 per cent. the difference between the heat absorption with the blackened and polished surfaces. When a plate of glass is substituted for the fluorite plate, the heat absorbed by the bolometer is reduced to about one-third of the above amounts; and if the platinum surface is polished, instead of blackened, the heat recorded is only 20 per cent. The latter figure agrees fairly well with the result given by Hagen and Rubens for the reflecting power of polished platinum.

APPENDIX C.

Abstracts from Various Papers relating to the Application of Heat Radiation from Luminous Flames to Siemens's Regenerating Furnaces.

In September, 1884, Mr. Frederick Siemens read a paper before the Iron and Steel Institute in which he described the application of radiant heat derived from luminous flames to such purposes as glass ovens and steel furnaces. The greater part of the paper was devoted to practical considerations; but in the discussion which followed, he expressed his views as to the theory of the action, and stated that, in order to obtain the best results, from the heat efficiency point of view, the operation should be divided into two parts. In the first part chemical combination took place; the flame was luminous; and the heat should be abstracted by radiation only. In order that the radiant heat might be a maximum, there should be a larger space, so that perfect combustion could take place without the gases coming into contact with any solid substance. This space was the furnace proper. In the second part, there was no combustion; the flame was non-luminous; and the heat should be abstracted from it by contact, as was done in the regenerative part of the furnace.

Siemens ascribed the radiant heat of the luminous flame to the incandescent particles of carbon, and said that, since flame is transparent to its own radiation, not only does the surface of the flame radiate, but also its interior. Hence a flame radiates far better than a solid substance. "A solid surface radiates only from its outer surface, and from that surface only towards one* direction, while a flame radiated from every point within it, and on its surface in every direction, or from every point of its entire volume towards every direction." If the area of a solid substance were doubled, it would only radiate twice as much; but if the surface of a (geometrically smaller) flame be doubled, the radiation would be four times as much.

He specially called attention to the advantage of this method of heating by referring to the experience obtained with glass pot furnaces in Dresden and in Bohemia, to which the new method of heating had been applied. There were great gains in every direction—50 per cent. more glass for the same expenditure of heat; less breakage of pots; the furnace lasted about six times longer; and higher temperatures were obtained, so that open pots could be used instead of closed ones. The glass was produced from cheaper materials, and was of superior quality.

* This is not true unless possibly when the surface is perfectly polished.

The statements made in the above paper were severely criticized by German engineers, and therefore on Oct. 26, 1884, Mr. Frederick Siemens read a paper at a meeting of the "Sachsischen Ingenieur und Architekten Verein" which was practically a repetition of his previous paper. In October, 1886, he read another paper before the Iron and Steel Institute, entitled "Combustion with Special Reference to Practical Requirements." In it, he confirmed what he previously stated, and added some remarks on dissociation—pointing out that if flame came into contact with heated surfaces there was a tendency to condense "one or other of the constituents," and that, therefore, dissociation could take place at comparatively low temperatures. Hence dissociation experiments should be carried out in large open spaces. He also remarked that the bunsen flame, being non-luminous, had but little radiating power. In 1886, he read another paper, in which he confirmed his previous statements. In this communication he stated that the radiating effect of luminous flames had been originally put into operation at his Dresden glass-works in 1877, and in his Bohemian glass-works in 1878; but the results were not published, for commercial reasons.

Mr. Jeremiah Head read a paper on the Siemens glass ovens before the British Association (Section G) at the Birmingham meeting in 1886. He pointed out that, with direct-heating, the furnace must be small; whereas with radiant heating the furnace can be, and must be, large. He stated that in these large spaces dissociation did not take place, although the temperatures were very high.

Mr. Frederick Siemens published another paper, in which he stated that the highest temperatures were observed where the flame did not come into contact with the furnace walls. Hence the highest temperature must be due to radiant heat. He again remarked that surfaces in contact with flame not only hindered combustion, but promoted dissociation.

Gustav Westmann published a scientific inquiry into the Siemens method of glass heating in a paper read before the "Verhandlungen des Vereins zur Beforderung des Gewerbfleisses," in 1886. An experiment on a large scale, lasting 24 hours, was made with a glass furnace, in which 25 tons of glass were melted by the gasification of 5 tons of coal and 5 tons of lignite. Full particulars of all measurements are given; and it is shown that the thermal efficiency was 41·9 per cent., the temperature 1200° C.

THE PRICE OF ELECTRICITY.

The numerous systems of charging for electricity in different parts of the country, and the conflict of opinion on the matter among electrical engineers, was the subject of a lengthy paper by Mr. E. W. Cowan read before the Economic Science and Statistics Section of the British Association at Sheffield last Thursday. A fundamental principle which the electrical industry has established as the ideal to be aimed at is that of charging upon the basis of equal rate of profit for every class of consumer. But the author argued that the "equal profit" system fails in the attainment of the best economic results, because the factor of demand is ignored in such a system. Of course, the intensity of the different classes of demand for electricity differs; and the author contended that the greatest economic advantage is realized when there is the closest and widest possible correspondence between the incidence of supply and the incidence of demand. Therefore the adjustment of price of supply according to the intensity of demand in the case of each class would secure a more efficient correspondence, and consequently greater aggregate economic advantage. The difficulties in giving effect to a practical system of classified tariffs were discussed; and it was shown, by reference to the successful operation of the system in railway working and in other industries, that these difficulties are not insurmountable. The adherence of electrical engineers to "equal profit" systems was discussed; they believing that such a system is ethically right, and that the classification of prices according to the nature of the demand would involve the introduction of an unfair element into the business. Mr. Cowan contended that, when the conditions are analyzed, it is found that there are no grounds for such a view; but that, from an ethical standpoint, classification can be resorted to without injury or loss to any class. The gain due to such a method was shown not to be a differential but a specific one which may be shared by all classes of consumer. The paper concluded with the expression of opinion that there is an immense potential demand for electricity for power and domestic heating and refrigeration, which could be rendered active by the sufficient lowering of price. The discussion on the paper rather showed that the general principles put forward might be accepted, but that the difficulties of translating them into a scientific tariff were too great.

The Livesey Bequests to Public Charities.—A few months after the death of Sir George Livesey, it was mentioned in the "JOURNAL" that, according to the terms of his will, a number of bequests had been made to public institutions, subject to the life interest of Lady Livesey. On her decease early the following year, the various sums specified became available for distribution among the charities selected; and we learn from Messrs. Hicklin, Washington, and Pasmore, the Solicitors under the wills, that the moneys were all paid over on the 24th ult.

GASEOUS COMBUSTION.

By WILLIAM A. BONE, D.Sc., Ph.D., F.R.S.

[Report presented to the British Association, Friday, Sept. 2.]

We have received from Professor Bone a revised print of this report, which was presented last Friday in Section B (Chemistry) of the British Association, at the meeting in Sheffield. It aims at summarizing the results of the principal researches upon the chemical aspects of gaseous combustion during the past thirty years, and is preceded by a synopsis.

INTRODUCTION.

The era in the scientific investigation of gaseous combustion with which this report is specially concerned was inaugurated some thirty years ago by the pioneering researches of the French savants, Mallard and Le Chatelier, and M. Berthelot, on the initial stages of "inflamation" and the setting-up of "detonation" in explosive mixtures, and by the equally fruitful discoveries by Harold B. Dixon and H. B. Baker concerning the part played by steam in combustion. Previous knowledge of the chemistry of fire had been mainly derived from the researches of Davy and his contemporaries (1815 to 1825), and those carried out or inspired by Bunsen some fifty years later. Davy's work, primarily undertaken in order to elucidate the causes of explosions in coal-mines, had disclosed, and brought within range of experimental inquiry, the broad facts connected with the ignition of explosive mixtures; the influence of narrow passages and of cold surfaces in extinguishing flames; the relative "combustibilities" and "explosion limits" of inflammable gases; and the effects of rarefaction and dilution on gaseous combustion. Finally, his notable discovery regarding the flameless combustion of hydrogen and of coal gas in contact with a glowing spiral of platinum, followed by the more systematic investigations of Dulong and Thénard, had drawn attention to the "intensifying" influence of hot surfaces on combustion, the importance of which has perhaps never been fully appreciated.

But the work of Davy—standing as it does between the ages of Lavoisier and Clausius, and singularly fruitful as it was in its immediate practical results—gave rise to no great theoretical developments. Soon after his death, the path of progress became choked with error. There arose the dogma of the selective combustion of hydrogen in hydrocarbon flames, which, although inconsistent with Dalton's experiments on the partial combustion of ethylene and methane, continued to dominate chemical science for more than half-a-century. There is no evidence that Davy himself ever countenanced this doctrine; but it possibly may have been suggested to his immediate successors by his mistaken views concerning the much higher combustibility of hydrogen as compared with hydrocarbons—a notion still widely prevalent.

Bunsen's researches upon gaseous combustion, while they did incalculable service to chemistry and metallurgy in introducing exact methods of gas analysis, and in elucidating the reducing action of carbon monoxide in the blast-furnace, unfortunately gave rise to certain misconceptions, due to unsuspected errors in the experimental methods employed. His experiments on the division of oxygen between carbon monoxide and hydrogen, which were originally undertaken to test the law of mass-action, are now recognized to have been vitiated by the fact that he worked with undried gases in a "wet" eudiometer. From his results, however, he concluded that the condition of equilibrium in such a case is determined by an assumed tendency to form certain "hydrates of carbon dioxide," and undergoes discontinuous alteration on gradual change in the relative proportions of the combustible gases originally present. But while this conclusion was afterwards disproved by the independent researches of H. B. Dixon and Horstmann, the underlying notion of "discontinuity" or variation *per saltum* in regard to gaseous combustion is still occasionally met with in technical literature.

A similar error crept into Bunsen's interpretation of the results of his measurements of the pressures produced when either hydrogen or carbon monoxide is exploded with half its own volume of oxygen at atmospheric pressure in a closed vessel. He contended that, in either case, one-third only of the gases combine in the first instance, whereby the temperature of the system is raised to some point between 2844° and 3033°; that it then falls by radiation to 2558°, between which point and 1146° a further one-sixth of the mixture combines, leaving the remaining half to burn as the system cools down to the ordinary temperature. This idea of combustion *per saltum* was revived again by Von Oettingen and Von Gernet in 1888, in connection with their photographic researches on the explosion of electrolytic gas. But it has been clearly proved by H. B. Dixon that their observations can be explained on other grounds.

Bunsen's first measurements of the rates at which flames are propagated in gaseous mixtures (namely, 34 metres per second for a mixture $2H_2 + O_2$, and 1 metre per second for a mixture $2CO + O_2$) have since been shown to apply only to the initial stages of an explosion, where the gases combine with relatively very slow velocities compared with those characteristic of "detonation." It was in the year 1881 that Berthelot, and independently Mallard and Le Chatelier, announced the discovery of the rapid acceleration of the initial velocity of inflammation and the final attainment of the enormously higher constant velocity of the "explosion wave."

SECTION I.—IGNITION TEMPERATURES AND THE INITIAL PHASES OF GASEOUS EXPLOSIONS.

Chemical change may be determined in a gaseous explosive mixture at a much lower temperature than its ignition point. Thus, if electrolytic gas be heated in a sealed bulb to a temperature somewhat higher than 400°, the formation of steam can usually be detected after a lapse of a few days. Between 450° and 500° the rate of combination, although considerably greater, would still be insufficient to cause any self-heating of the mixture. If, however, the temperature of the enclosure be further slowly raised, a point (probably about 550°) would soon be reached at which self-heating of the mixture would begin. Its temperature would thus be raised above that of the enclosure, and the rate of combination rapidly accelerated until explosive combustion would be set up. The precise temperature at which this would occur would obviously depend upon the amount of slow combustion which had taken place during the preliminary heating-up of the mixture. Thus it follows that the only way of determining the true ignition temperature of such a mixture, undiluted by the products of its own slow combustion, would be either to make the preliminary heating-up period negligibly short, or, better still, to heat separately the combustible gas and the air or oxygen to the ignition temperature before allowing them to mix.

The work of Victor Meyer and his pupils, as also that of Hélier and Emich, which yielded very discordant results for the ignition temperatures of mixtures of the commoner inflammable gases with oxygen, doubtless suffered from the large amount of flameless combustion which occurred before the temperature of the mixture as a whole had been raised to the true ignition-point.

Quite recently, however, H. B. Dixon and H. F. Coward, using an apparatus in which the combustible gas and air or oxygen were separately heated to the temperature of the enclosure before being allowed to mix, succeeded in fixing, within narrow limits, the ignition temperatures at atmospheric pressure of a number of gases. In the cases of hydrogen, carbon monoxide, and acetylene, the ignition temperatures were practically the same in air as in oxygen, thus:

	In Air.		In Oxygen.
Hydrogen	580°—590°	..	580°—590°
Carbon monoxide (moist)	644°—658°	..	637°—648°
Acetylene	406°—440°	..	416°—440°

In most other cases, however, the limiting temperatures observed in air were higher than in oxygen, thus:

	In Air.		In Oxygen.
Methane	650°—750°	..	556°—700°
Ethylene	542°—547°	..	500°—519°
Cyanogen	850°—862°	..	803°—818°

Another notable fact is that, in an homologous series of hydrocarbons, the limiting ignition temperatures appear to fall as the series is ascended. Thus we have (in oxygen):

Methane, 556°—700°. Ethane, 520°—630°. Propane, 490°—570°.

During 1906-7 K. G. Falk, acting on a suggestion made by Nernst, endeavoured to determine the ignition points of various mixtures of hydrogen and oxygen by compressing them in a steel cylinder by means of a weight falling on a piston. Assuming that (1) the mixture was heated adiabetically and uniformly throughout its whole mass until it reached the ignition point, (2) that the whole then detonated instantaneously, and (3) that the downward movement of the piston was arrested at the moment of ignition, he calculated the ignition temperatures under adiabatic compression shown in the table given below.

H. B. Dixon, in a recent criticism of Falk's assumptions, contends that while (1) may be in certain cases practically true, (2) and (3) cannot be allowed, and also that Falk's results are unreliable on account of his having neglected to stop the descent of the piston the moment the gases were brought to the true ignition point. Adopting this necessary precaution, Dixon has repeated Falk's experiments, with results which compare as follows, when δ is assumed to be 1·40 in all cases:

Mixture.	Ignition Temperature under Adiabatic Compression.		
	Falk.		Dixon.
$4H_2 + O_2$	605°	..	—
$2H_2 + O_2$	540°	..	536°
$H_2 + O_2$	514°	..	530°
$H_2 + 2O_2$	530°	..	520°
$H_2 + 4O_2$	571°	..	507°

Using the specific heats of hydrogen and air found by Joly under high pressures, Dixon calculates the ignition point of electrolytic gas to be 557°, from his experiments on adiabatic compression. From Dixon's results, it would also appear that successive additions of oxygen to electrolytic gas regularly lower the ignition-point.

We are principally indebted to the photographic researches of H. B. Dixon and his pupils for the most notable recent additions to our knowledge concerning the initial phases of explosion and the phenomena associated with the setting-up of detonation in gaseous mixtures. The first investigators to use a photographic method were Mallard and Le Chatelier in their researches on the initial phases of gaseous explosions. They recorded the movement of the flame along a horizontal glass tube on a sensitized plate moving vertically, thus obtaining a graph compounded of the two velocities. Failing to obtain any satisfactory records with such feebly luminous flames as those yielded by mixtures either of carbon monoxide or of hydrogen with oxygen, they

employed mixtures of carbon disulphide with oxygen or nitric oxide, which they regarded as typical of all oxygen or air mixture respectively.

The behaviour of these mixtures was found to differ according as they were ignited near (*a*) the open or (*b*) the closed end of a tube. In the case of (*a*) the flame proceeded for some distance down the tube at a practically uniform velocity, which is the true rate of propagation "by conduction." With the mixture CS_2+6NO, this state was succeeded by an oscillatory period; the flame swinging backwards and forwards with increasing amplitudes, and then either dying out altogether or giving rise to "detonation." With the oxygen mixtures, the initial period of uniform slow velocity was shorter, and appeared to be abruptly succeeded by detonation without the intervention of any oscillatory period. When the nitric oxide mixtures were ignited near the closed end of the tube, the forward movement of the flame was uniformly accelerated until detonation was set up.

According to Le Chatelier the following numbers represent in metres per second the true initial rates of inflammation (*i.e.*, of propagation of flames "by conduction") for various mixtures:

Hydrogen and Air.

Hydrogen, per cent.	10	20	30	40	50	60	70
Metres, per second	0·60	1·95	3·30	4·37	3·45	2·30	1·10

Methane and Air.

Methane, per cent.	6	8	10	12	14	16
Metres, per second	0·03	0·23	0·42	0·61	0·36	0·10

Acetylene and Air.

Acetylene, per cent.	2·9	5	7	9	15	22	40	60	64
Metres, per second	0·1	2	4	6	3	0·4	0·22	0·07	0·05

Coal Gas and Air.

Gas, per cent.	8	10	12	14	15	17	20	24
Metres, per second	0·30	0·50	0·72	0·93	1·05	1·27	0·80	0·40

Oxygen Mixtures.

$2CO + O_2$	2 metres per second.
$2H_2 + O_2$	20 ,, ,,
$CS_2 + 3O_2$	22 ,, ,,
$C_2H_2 + 2\frac{1}{2}O_2$	200 ,, ,,

It should be noted that for mixtures of the same gas with various proportions of air, the initial rate of inflammation attains a maximum when the combustible gas is present in considerable excess of that required for perfect combustion.

H. B. Dixon's experimental method consisted in photographing the explosion flame travelling along a horizontal tube on a highly sensitive film rotated vertically with a constant high velocity (varying, however, between 25 and 50 metres per second in different experiments); the explosion tube being placed at such a distance from the camera that the size of the image was about one-thirtieth that of the flame. In this way it was found possible to analyze the progress of an explosion from its point of origin up to the final attainment of its maximum force and velocity in "detonation." The investigation also included the discovery of the wave of "retonation," which is thrown back through the still burning gases from the point where detonation starts (a phenomenon also independently discovered by Le Chatelier in 1900), of the effects of collision between two explosion waves, and of the passage of reflected waves through the hot products of explosion.

The phenomena associated with the development of an explosion in a gaseous mixture, fired in a closed tube by a spark passed between wires a few inches from the closed end, are clearly shown in the photograph reproduced in fig. 1, which is analyzed in the diagram fig. 2. This photograph was taken during an experiment in which carbon disulphide was exploded with a quantity of oxygen represented by the expression $CS_2 + 5O_2$. The flame, in starting at the point O, sends out invisible compression waves in both directions along the tube, which travel in advance of the flame with the velocity of sound through the unburnt gases, as represented by the dotted lines O M, O N in the diagram. The flame itself, travelling at first more slowly than the compression waves, traces the curves O A and O B. The compression wave O N, on reaching the closed end of the tube, is reflected back again as N C, and, on meeting the flame (which is still travelling in the direction O A), retards it, and passes thence through the hot and probably still burning gases as the visible wave C D. An instant later it overtakes at D the front of the flame, travelling in the direction O B, thereby accelerating it and increasing its luminosity in consequence of the quickened combustion. The flame then continues to move forward with rapidly accelerated velocity until "detonation" is set up at the point E. At this point a strongly luminous wave of compression E G (the "retonation wave") is sent backwards through the still burning gases, which, on reaching the near end of the tube, is reflected back again as G H. The "detonation wave" E F passes onwards through the mixture with its characteristic uniform high velocity and intense luminosity. Fig. 3 is a similar photograph which shows the development of

Fig. 1

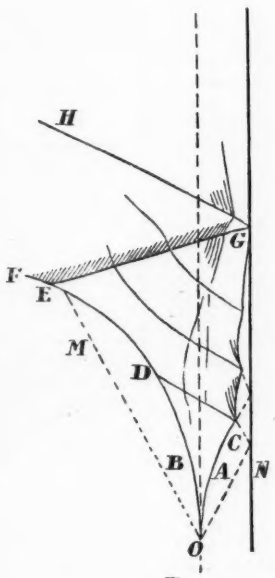


Fig. 2.

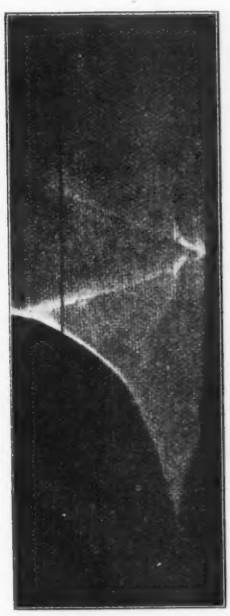


Fig. 3.

"detonation" and the phenomenon of "retonation" in the case of a mixture of cyanogen and oxygen ($C_2N_2+O_2$) fired near the closed end of a tube.

Except in special circumstances (*e.g.*, when it is reinforced by another reflected wave) the velocity of the retonation wave is always inferior to that of detonation. Thus Le Chatelier gives 2990 metres per second for the "detonation wave" and 2330 metres per second for the "retonation wave" in an equimolecular mixture of acetylene and oxygen. When, however, the "retonation wave" is developed just at the closed end of a tube (*e.g.*, when the explosive mixture is fired at such a distance from the closed end that "detonation" is set up just as the flame arrives at the end) it may be reinforced by a reflected wave, in which case its velocity cannot be distinguished from that of a true "detonation."

The explanation of the intense luminosity of the retonation wave, and its higher velocity than sound through the exploded gases, is to be found in the fact that the combustion during the initial stages of an explosion is very much slower than when detonation is set up. Under the extreme conditions of "detonation" the temperature of each successive layer of the explosive mixture is suddenly raised to the ignition point by adiabatic compression; and it is probable that a large proportion of collisions between chemically opposite molecules are fruitful of change. The whole combustion is probably completed in an immeasurably short interval of time, as the result of a comparatively limited number of successive molecular collisions. But during the initial period of the explosion ("inflammation") not only is the flame propagated with a much slower velocity, but also the actual process of combustion is much more prolonged than in detonation; and at the moment when detonation is set up combustion is still proceeding in the layers of gas for some distance behind the flame-front. The "retonation" wave, in passing backwards through these layers, quickens this residual combustion, and is

itself thereby rendered highly luminous. This interpretation is supported by repeated observations of Dixon, that the collision of two flames in neither of which "detonation" has been determined, will frequently give rise to reflected waves more rapid and more luminous than the incident waves. There can be little doubt as to the important part played by reflected waves in determining the violent shattering effects associated with gaseous explosions on a large scale.

Section II.—The Explosion Wave.

Berthelot and Vieille, in announcing their discovery of the development of detonation ("l'onde explosive") in gaseous explosions, described it as "*une certaine surface régulière, où se développe la transformation, et qui réalise un même état de combinaison, de température, de pressure, etc. Cette surface, une fois produite, se propage ensuite, de couche en couche, dans la masse tout entière, par suite de la transmission des chocs successifs des molécules gazeuses amenées à un état vibratoire plus intense en raison de la chaleur dégagée dans leur combinaison, et transformées sur place, ou, plus exactement, avec un faible déplacement relatif . . .*" Such conditions are comparable with those of a sound wave passing through the gaseous mixture, with, however, the important difference that, whereas a sound wave is propagated from layer to layer with a small compression and a velocity determined solely by the physical condition of the vibrating medium, it is an abrupt change in chemical condition which is propagated in the explosion wave, and which generates an enormous force as it passes through each successive layer of the medium. Berthelot considered that the mean velocity of the translation of the molecules of the products of combustion, retaining the total kinetic energy corresponding to the heat developed in the reaction, may be regarded as the limiting maximum rate of propagation of the explosion wave (θ), which would be given, in metres per second, by the equation

$$\theta = 29{\cdot}354\sqrt{\quad}-$$

where T is the absolute temperature and ρ the density of the products referred to air. In calculating T, Berthelot made two erroneous assumptions—namely, (1) that the specific heats of the products are independent of temperature and equal to the sum of the specific heats of the reacting gases, and (2) that the gases burn under conditions of constant pressure. He was also of opinion that, owing to the high pressures generated, dissociation plays no appreciable part in the phenomena of the wave.

In their experimental work, Berthelot and Vieille proved that the velocity of the explosion wave is independent of the length of the column of gas traversed, and of the material or diameter of the tube employed (at least above a certain small limiting diameter). It was also immaterial whether the tube was laid out straight, coiled round a drum, or even zigzagged. They also concluded that the velocity is independent of initial pressure. But this is not strictly correct, as H. B. Dixon has since shown. The rate increases slightly with the initial pressure, attaining a nearly constant value at a pressure of about two atmospheres.

H. B. Dixon (the bearing of whose researches upon the question of the mechanism of combustion will be discussed later) modified Berthelot's theory in the following particulars: namely, by assuming (1) that the explosion wave is carried forward by movements of molecules of density intermediate between that of the products of combustion and that of the unburnt gas; (2) that the gases are heated at constant volume; (3) that the temperature of the gas propagating the wave is double that due to chemical reaction alone; (4) that the temperature is increased when the chemical volume of the products is larger, and diminished when it is smaller, than that of the unburnt gases; (5) that the velocity of a sound wave is only 0·7 of the mean velocity of the molecules in the gas.* Dixon's formula for the rate of explosion of a given mixture is, therefore, as follows:—

$$v = 0{\cdot}7 \times 29{\cdot}354\sqrt{\frac{\left(2\frac{Q}{Cv} + T\right)\left(\frac{v_2}{v_1}\right)^{\gamma - 1}}{\rho}}$$

where Q = the heat developed by the reaction, v_2 and v_1 = the chemical volumes of the products and unburnt gases respectively, ρ = the mean density of the products and the unburnt gases, and Cv = the specific heat of the products at constant volume, which Dixon wrongly assumed to be independent of the temperature, T = the temperature in C°, and γ = ratio of specific heats.

But, whereas the values of v, calculated by this formula, do in many instances correspond with those actually found (*e.g.*, for mixtures of cyanogen and oxygen, and in nearly all cases where the detonating mixture is largely diluted with an inert gas), there are a large number of cases of undiluted detonating mixtures in which the agreement is not good (*e.g.*, for $2H_2 + O_2$ the calculated value is 3416, whereas that actually found is only 2821 metres per second). Dixon ascribed such discrepancies to partial dissociation of the products in the wave; but there is now little doubt that the formula does not hold good, as Dixon himself readily enough admits.† Nevertheless for many years it was a valuable working hypothesis and inspired much fruitful investigation.

In 1899, D. L. Chapman—following up a suggestion made by Schuster at the time when Dixon's memoir was first published—deduced a formula for rates of explosion from Riemann's equation for the propagation of an abrupt variation in the density and the pressure of a gas, on the assumption that such a variation can be propagated without change of type. According to this view, the explosion wave is to be regarded as a wave of compression not in a homogeneous medium, but in a medium which is discontinuous in the vicinity of the wave-front. It is assumed (1) that the "front" of the wave (*i.e.*, from the unexploded gas to the point of maximum pressure) does not alter in character, or, in other words, that every portion of the wave travels with the same velocity; (2) that the velocity is the minimum velocity consistent with (1); and (3) that at the point of maximum pressure the chemical change concerned in the propagation of the wave is complete. The unburnt gases immediately in front of the waves are, of course, fired by compression; and the abrupt variation in the density and pressure of the medium is due to the chemical change. Chapman's formula for the velocity of the explosion wave in centimetres per second is:

$$V = \sqrt{\frac{2RJ}{\mu C_v^2}\left[\{(m-n)C_p + mC_v\}C_p t_o + (C_p + C_v)h\right]},$$

where R = the gas constant (1·985), J = the dynamical equivalent of heat (42×10^6 ergs), μ = the gram equivalents of the mixture exploded (*e.g.*, 58 in the case of $C_2H_2 + O_2$), n and m = the number of gaseous molecules before and after the chemical change in the wave, C_p and C_v = the mean specific heats of the products at constant pressure and volume respectively, h = the total heat generated in the wave, and t_o = the initial temperature (abs.) of the mixture exploded. From the fact that the dilution of electrolytic gas ($2H_2 + O_2$) with oxygen lowers its rate of explosion a little more than a corresponding dilution with nitrogen, Chapman considers it improbable that there is any appreciable dissociation of steam in the wave. He assumes that the molecular heat of steam rises more rapidly with temperature than that of a diatomic gas; and that the molecular heats of oxygen, hydrogen, nitrogen, and carbon monoxide may for practical purposes be considered as equal at any given temperature. Selecting some seventeen of Dixon's found rates of explosion, he has calculated by means of his formula the corresponding molecular heats and temperatures; arriving at the following results for C_v at intermediate temperatures by interpolation;—

	Temperature	4300°	4000°	3700°	3400°	3100°	2800°	2500°
C_v	Steam	14·750	14·297	13·750	13·102	12·250	11·040	9·797
	Diatomic gases	7·707	7·674	7·641	7·608	7·575	7·542	7·509

With the aid of this series of numbers he proceeded to apply his formula to the calculation of the rates of explosion of some forty other mixtures investigated by Dixon; finding in all cases close agreement between the found and calculated values, of which the following may suffice as examples:—

Mixture Exploded.	Products in the Wave.	Temperature.	Rate of Explosion, Metres per Second.	
			Calculated.	Found.
$2H_2+2N_2O$	$2H_2O+2N_2$	3813°	2408	2305
$4H_2+2N_2O$	$2H_2O+2N_2+2H_2$	3077°	2604	2545
$6H_2+2N_2O$	$2H_2O+2N_2+4H_2$	2612°	2720	2705
$2H_2+2N_2O+2N_2$	$2H_2O+4N_2$	3077°	2097	1991
$C_2H_4+2O_2$	$2CO+2H_2O$	4365°	2619	2581
$C_2H_4+3O_2$	$2CO+2H_2O+O_2$	3882°	2348	2368
$C_2H_2+O_2$	$2CO+H_2$	5029°	3101	2961
CH_4+O_2	$CO+H_2O+H_2$	2772°	2502	2528
$2CH_4+3O_2$	$2CO+4H_2O$	3764°	2485	2470
$2CH_4+3O_2+N_2$	$2CO+4H_2O+N_2$	3513°	2353	2349

A characteristic feature of detonation is the extremely short duration of chemical action and subsequent rapid cooling of the products, as compared with ordinary combustion. Some years ago the writer, working in conjunction with Bevan Lean, under Professor H. B. Dixon's direction, found by a photographic method that the duration of luminosity in each successive layer of gas in the detonation of electrolytic gas is certainly less than $\frac{1}{10000}$ second—a much shorter interval of time than was required to shatter a tube of thin glass attached to the end of the explosion coil used. This tube, though it was invariably smashed by the force of the explosion, always appeared perfectly intact in the photograph. Dixon's subsequent photographic researches have demonstrated the abrupt suddenness with which the gases attain the maximum temperature in detonation, the intensity and short duration of luminosity, and the subsequent rapid cooling, as compared with ordinary combustion. Moreover, high as is the temperature attained, there is no evidence of any considerable dissociation of steam in the wave; for, despite the instantaneous cooling of the products, there is less than 1 per cent. of the gases left uncombined after the wave has passed through electrolytic gas ($2H_2 + O_2$).

Influence of an Excess of an Inert Gas upon the Rate of Explosion.—Writing Chapman's formula as follows:—

$$V^2 = \frac{2RJ}{\mu C_v^2}\left[\{(m-n)\,C_p + mC^v\}\,C_p t_o + (C_p + C_v)h\right]$$

and putting $\frac{2RJ}{\mu C_v^2} = A$, and the terms between the square brackets = B, it will be immediately perceived that the addition of an inert diatomic gas (*e.g.*, H_2, N_2, or O_2) to a given explosive

* The reader is referred to the original memoir in the "Philosophical Transactions" for 1893, for details of the argument.

† See his recent Presidential Address to the Chemical Society.

mixture will affect the values of both A and B, but not necessarily in the same direction. It will increase the value of μ and diminish the values of C_v and C_p, partly by lowering the temperature in the wave and partly also (if steam or carbon dioxide be formed in the wave) by reason of its own specific heat being lower than that of the undiluted products. It will also increase the value of m without altering $(m - n)$. If it be assumed that the molecular heats of the three diatomic gases under consideration are, for all practical purposes, equal at any given temperature, it will be at once seen that an equal dilution of a given explosive mixture with any one of the three gases, while it will have an equal effect on all terms included under B, may either increase or diminish the value of A, according as to whether or not the *plus* effect of the lower value of C^v is counterbalanced by the *minus* effect of the increase in μ. If the latter effect be small, as would be the case with hydrogen as the diluent, the value of A would on the whole be increased; whereas if the increase in μ were large, as would be the case with nitrogen or oxygen as the diluent, the value of A would on the whole be diminished.

As an example of the probable effects of the equal dilution of a given explosive mixture with each of the three gases in question, the case of an equimolecular mixture of hydrogen and nitrous oxide, fired at 10° and 760 mm., may be cited as follows:—

Mixture.	h	m	$m-n$	μ	C_v	Temp.	A	B	V. in Metres per second. Calculated.	Found.
H_2+N_2O . .	132,500	4	0	92	10·81	3813°	15,640	3,758,750	2425	2305
$H_2+N_2O+2H_2$		6	0	96	9·10	3077°	20,980	3,251,500	2612	2545
$H_2+N_2O+2N_2$		6	0	148	9·10	3077°	13,610	3,251,500	2104	1991
$H_2+N_2O+2O_2$		6	0	156	9·10	3077°	12,830	3,251,500	2042	—

An inspection of the figures under columns A and B will at once make it clear why, whereas dilution with hydrogen is invariably found to increase the rate of explosion of a given mixture, an equal dilution with nitrogen or oxygen invariably diminishes it, and also why the retarding influence of oxygen must always be greater than that of an equal proportion of nitrogen. The following examples, taken from Dixon's memoir, may be cited in support of the above argument:

Effects of Dilution upon the Rate of Explosion of Electrolytic Gas.

Mixture Exploded.	Rate. Metres per Second.
$2H_2+O_2$	2817
$2H_2+O_2+2H_2$	3268
$2H_2+O_2+4H_2$	3527
$2H_2+O_2+6H_2$	3532
$2H_2+O_2+O_2$	2328
$2H_2+O_2+3O_2$	1927
$2H_2+O_2+N_2$	2426
$2H_2+O_2+3N_2$	2055

Effects of Dilution with Hydrogen upon the Rate of Explosion of Hydrogen and Chlorine.

Mixture	H_2+Cl_2 ..	$2H_2+Cl_2$ ..	$3H_2+Cl_2$
Rate—metres per second	1729 ..	1849 ..	1855

The Burning of Gaseous Carbon.—Of the many important facts brought to light during the course of Dixon's investigation, none are of greater interest than those relating to the burning of gaseous carbon in the explosion wave, as illustrated by the case of cyanogen. In view of the fact that the molecular heat of combustion of cyanogen, when burnt completely to carbon dioxide, is 259·6 kilogram C. units, whereas, if burnt to carbon monoxide, it would only be 123 units, it might be expected that the rate of explosion for a mixture $C_2N_2 + 2O_2$ would be much higher than for $C_2N_2 + O_2$, if gaseous carbon is primarily burnt to carbon dioxide in the wave. The exact opposite is the case, however, as the following results show:

Mixture.	Products.	Rate.
$C_2N_2+O_2$ . .	$2CO+N_2$ . .	2728
$C_2N_2+2O_2$ . .	$2CO_2+N_2$ . .	2321

metres per second.

Still more cogent is the evidence in favour of the initial formation of carbon monoxide in the wave, when the following figures are considered:

	$C_2N_2+O_2$	$C_2N_2+O_2+N_2$	$C_2N_2+O_2+O_2$
Rate—metres per second	2728 ..	2398 ..	2321

The conclusion to be drawn from the preceding figures is that cyanogen is initially burnt to carbon monoxide and nitrogen in the wave itself, any excess of oxygen afterwards burning up the carbon monoxide as the gases cool down in rear of the wave.

This conclusion was driven home by Dixon, in conjunction with Strange and Graham, by photographing on a sensitive film, rotated at a speed of about 1500 metres per minute, the explosion flame in the case of the three mixtures (*a*) $C_2N_2+O_2$, (*b*) $C_2N_2+O_2+N_2$, (*c*) $C_2N_2+2O_2$. In each case the flame was photographed, after detonation had been set up, as it dashed past a glass window inserted into the lead explosion coil. The image obtained in the case of (*a*) showed an intensely brilliant flame (the explosion wave), slightly drawn out in tapering form; in the case of (*b*), with nitrogen as diluent, the flame was less brilliant and somewhat more drawn out than in (*a*); but with (*c*) the flame while no more luminous than in (*b*), was drawn out to great length, owing to the continued combustion of carbon monoxide in the rear of the wave. The diagram fig. 4 (approximately to scale), will convey an idea of the relative durations of the flames in the three cases:—

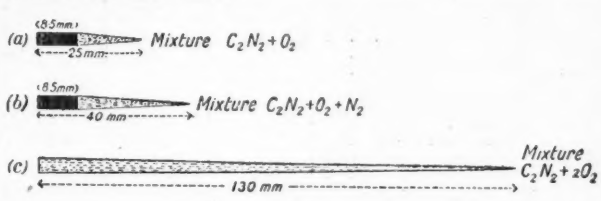


Fig. 4.

The Burning of Hydrocarbons in the Wave.—It was during the course of measurements of the rates of explosion of hydrocarbons with varying proportions of oxygen in 1891-92 that Dixon and his collaborators rediscovered facts (orginally set forth by Dalton in his "New System of Chemical Philosophy") which finally disposed of the dogma that in a deficient supply of oxygen a "selective" burning of hydrogen occurs. It was found that when either ethylene or acetylene is detonated with its own volume of oxygen the ultimate products consist almost entirely of carbon monoxide and hydrogen. The rates of explosion, while they do not reveal the real mechanism of the combustion, show very clearly that, as in the case of cyanogen, the carbon of a hydrocarbon is burnt initially to the monoxide in the wave itself, the formation of the dioxide being an after-effect and taking place in the rear of the wave. In the cases of methane and acetylene, the fastest rates are observed with equimolecular mixtures, whereas with ethylene the rate increases with the proportion of oxygen up to the limit $C_2H_4 + 2O_2$. As the question of the mechanism of hydrocarbon combustion will be fully discussed later, the following rates of explosion, as determined by Dixon, may now be given without further comment:

(A) *Methane and Oxygen in Varying Proportions, Fired at 10° and 760 mm.*

Mixture . .	CH_4+O_2	$CH_4+1\frac{1}{2}O_2$	CH_4+2O_2	CH_4+3O_2*	CH_4+4O_2
Rate—metres per second	2528	2470	2322	2146	1963

* Compare this with the 2154 metres per second observed for $CH_4+1\frac{1}{2}O_2+1\frac{1}{2}N_2$ as showing the inertness of at least the moiety of the oxygen in the wave.

(B) *Ethylene and Oxygen in Varying Proportions, Fired at 10° and 760 mm.*

Mixture . .	$C_2H_4+O_2$	$C_2H_4+2O_2$	$C_2H_4+3O_2$*	$C_2H_4+4O_2$	$C_2H_4+6O_2$
Rate—metres per second .	2507	2581	2368	2247	2118

* Compare this with the 2413 metres per second observed for $C_2H_4+2O_2+N_2$.

(C) *Acetylene and Oxygen in Varying Proportions, Fired at 10° and 760 mm.*

Mixture	$C_2H_2+O_2$	$C_2H_2+1\frac{1}{2}O_2$	$C_2H_2+2\frac{1}{2}O_2$*
Rate—metres per second. .	2916	2716	2391

* Compare this with the 2414 metres per second observed for $C_2H_2+1\frac{1}{2}O_2+N_2$.

Section III.—Pressures Produced by Gaseous Explosions.

Many investigators, from the time of Bunsen's well-known experiments in 1867 onwards, have measured the pressures produced in gaseous explosions, with doubtless considerable success so far as what may be termed the mean effective pressures are concerned. As the subject is at present engaging the attention of a Committee appointed by the Association in 1907, any lengthy reference to it in this report may seem superfluous. Nevertheless, if only for the sake of completeness, a brief *résumé* of our present knowledge may not here be out of place. The explosion vessel employed by Bunsen was a stout glass tube, 8·15 cm. long, 1·7 cm. internal diameter, and of 18 c.c. capacity. It was closed by a suitable valve, the load on which could be adjusted till it was just lifted when the explosive mixture was fired by means of a powerful spark passed along the axis of the tube. Bunsen considered that the combustion would occur under adiabatic and "constant volume" conditions; and he identified the rate of ignition of a particular mixture with that of the completion of chemical change. In calculating from his results the corresponding flame temperatures, he assumed the constancy of the specific heats of steam and carbon dioxide. Finding that the pressures recorded in the cases of electrolytic gas and of a mixture of carbon monoxide and oxygen in their combining proportions (namely 9·5 and 10·1 atmospheres respectively) were somewhat less than one-half of those theoretically required on the above assumptions, he concluded that in each case combustion had proceeded *per saltum*, owing to the supposed theoretical flame temperatures exceeding the limits at which steam and carbon dioxide respectively are completely dissociated. The problem was again attacked independently by Mallard and Le Chatelier in 1883, and by Berthelot and Vieille in 1885. The last-named fired various gaseous mixtures at atmospheric pressure in a spherical iron bomb, measuring the effective pressures by the movement of a light piston working against a spring in a tube attached to the bomb. In order to gain some information as to the possible cooling influence of the walls upon the effective pressures recorded, three bombs of different capacities—namely, A, of 300 c.c., B, of 1500 c.c., and C, of 4000 c.c.—were employed. The

results, expressed in each case as atmospheres in excess of the atmospheric pressure, were as follows:

Bomb.		A.	B.	C.
Capacity in cm.		300	1500	4000
Surface in cm.		216	648	1220
Surface per unit volume.		0·72	0·43	0·33
Diameter in cm.		6·0	14·2	21·7
Length of firing piece in cm.		6·3	5·3	6·3
Travel of flame before reaching the piston in cm.		9·1	16·3	24·8
Mixture exploded.		Atms.	Atms.	Atms.
	$2H_2 + O_2$	7·41	9·69	9·80
	$2CO + O_2$	9·29	9·93	10·21
	$CH_4 + 2O_2$	13·94	14·81	16·31
	$C_2N_2 + O_2$	—	—	25·11
	$C_2N_2 + 2O_2$	—	—	20·96
Pressures				
Time required for flame to travel from firing piece to piston of indicator.		Second.		Second.
Mixture	$2H_2 + O_2$	0·00104	—	0·00214
	$2CO + O_2$	0·01286	—	0·01551

Perhaps the most notable feature about these results is the smallness of the difference between the pressures observed with bombs A and C in any particular case. These differences might at first sight be attributed to the (supposed) much smaller cooling influence of the walls of bomb C as compared with bomb A. But if this were the true explanation, the difference should be greater with the slow-burning $2CO+O_2$ mixture than with the fast-burning $2H_2+O_2$, whereas the opposite was the case. Moreover, the fact that dilution of the mixture $2H_2+O_2$ with twice its own volume of nitrogen almost obliterated the difference between the pressures observed in the cases of bombs A and C (the ratio $\frac{p_C}{p_A}$ for the diluted being 0·95, as against 0·76 for the undiluted mixture) is all against the cooling theory. The more probable explanation is to be found in the fact that, owing to the much longer travel of the flame before it reached the piston of the indicator in bomb C as compared with A, the explosion would be in a more advanced phase of its development, and this would be most marked in the case of the fastest burning mixtures. Berthelot and Vieille assumed that in the above experiments completion of the combustion synchronized with the attainment of maximum pressure, and attributed the marked disparity between the observed pressures (bomb C) and those calculated from the heats of combustion (on the assumption of adiabatic conditions) to a rapid increase in the specific heats of steam and carbon dioxide at high temperatures. They considered it improbable that dissociation phenomena play any conspicuous part in limiting the pressures attained.

Mallard and Le Chatelier, who used a Bourdon gauge for measuring pressures, and applied a "cooling correction" to their results, arrived at practically the same conclusions as Berthelot and Vieille respecting both the increase of the specific heats of steam and carbon dioxide with temperature and the small if not negligible influence of dissociation. They calculated that the temperature of the flame when moist electrolytic gas is exploded in a closed vessel at atmospheric pressure is about 3350°, and that the mean molecular heat of steam at constant volume between 0° and 3350° is 16·6. In the case of the mixture $2CO+O_2$ they concluded that the molecular heat (C_v) of carbon dioxide rises to 13·6 at 2000°, above which temperature dissociation at once comes into play.

The experience of all subsequent investigators has confirmed that of Bunsen and the French savants, in so far as the facts of the case are concerned. It may be taken as commonly agreed that the maximum effective pressures recorded when gaseous mixtures are fired in closed vessels are always considerably less than those calculated on the assumption that the whole heat of combustion is communicated without loss to the products, and that the specific heats of the products do not vary with temperature. Thus in the case of Mr. Dugald Clerk's experiments, where hydrogen and air mixtures were exploded at atmospheric pressure in a closed cylindrical vessel, 21 cm. in length, 17·75 cm. diameter, and 5·2 litres capacity, the maximum pressures, recorded by a Richards's indicator making a graph on a revolving drum, varied between about 50 and 60 per cent. of those calculated on the above assumptions, as follows:

Mr. Dugald Clerk's Experiments (1884-5).

	Volumes Air to 1 Volume Hydrogen					
	2½		4		6	
Maximum pressure found	6·44	..	5·63	..	3·80	Atmospheres
Maximum pressure calculated on the above assumptions	13·0	..	9·45	..	7·0	Atmospheres

Another feature (since confirmed by many subsequent observers) brought out by Mr. Clerk's experiments was the very short time required for the attainment of maximum pressure relative to the subsequent cooling period. Thus in the case of the mixture of 1 volume hydrogen with 4 volumes air, the maximum pressure of 68 lbs. per square inch above the atmospheric was attained in 0·026 second, whereas the subsequent cooling period occupied 1·05 seconds, or forty times as long.

The great disparity between the found and "calculated" maximum pressures has been attributed by the various investigators concerned to one or other of the following causes:

1. *To the marked increase in the specific heats of steam and carbon dioxide with temperature.* That this is a true cause is now generally admitted. As, however, the subject was fully dealt with in the first report of the Committee appointed by the Association in 1907 for the investigation of gaseous explosions, it need not be considered in any detail here.

2. *To the fact that in ordinary gaseous explosions, where detonation has not been determined, combustion is by no means instantaneous, and may not be completed within the period required for the attainment of maximum pressure.* Mr. Dugald Clerk put forward this suggestion as long ago as 1886 in criticizing the conclusions of Mallard and Le Chatelier respecting the great increase in the specific heats of steam and of carbon dioxide with temperature. He considered it highly probable that combustion extends far into the actual "cooling period" in gaseous explosions (and hence the long drawn out "cooling curve"); so that the system loses a certain part of the heat of combustion before the chemical action is completed. This idea of a continued combustion finds support in H. B. Dixon's photographic researches; and chemists generally will concede its reality in any gaseous combination in which detonation is not determined. But to what extent it may be held to affect the pressures actually recorded by explosions is still a matter of conjecture.

3. *To loss of energy by direct radiation.* Thus in the explosion of a mixture of hydrogen and oxygen it is conceivable that the initial action results in the formation of an intensely vibrating molecular complex from which steam issues as the first recognizable product. Some experiments made in 1890 by Robert von Helmholtz showed that non-luminous hydrocarbon flames radiate about 5 per cent. of the heat of combustion of the gas, and more recent experiments by Professor Callendar and Mr. Nelson show that the heat radiated from an ordinary non-luminous bunsen flame may amount to between 15 and 20 per cent. of the total heat of combustion, a figure which is in close agreement with the results of experiments carried out by Mr. E. W. Smith under the auspices of the Gas-Heating Research Committee appointed by the Institution of Gas Engineers in conjunction with the University of Leeds. There is, therefore, little doubt but that this cause is truly operative in gaseous explosions.

4. *To dissociation of products (steam and carbon dioxide).* In the case of two combining gases producing a dissociable product, it is clear that if the average temperature in the system reaches that at which dissocation begins, the combustion must be delayed while heat escapes from the system by radiation and conduction. Qualitatively, the partial dissociation of steam and carbon dioxide has been proved at temperatures which are certainly exceeded by those of explosion flames; but it may be urged that, inasmuch as all experiments upon dissociation have up to the present involved contact with hot solid surfaces, there is no positive evidence that the phenomenon would play any conspicuous part in an unconfined gaseous system. On the other hand, there is direct experimental evidence of the attainment of enormously high temperatures in the explosion wave—temperatures which would generally be considered as far beyond that of the initial, or perhaps even of the complete, dissociation of steam or of carbon dioxide. Moreover, the fact that the rate of explosion of electrolytic gas is retarded rather more by an excess of oxygen than by a corresponding excess of nitrogen, is inconsistent with the supposition of any appreciable dissociation of steam in the explosion wave; and photographic records give no evidence of continued combination in the rear of the wave except where two or more chemical stages are in the combustion.

Section IV.—Influence of Moisture upon Combustion.

Thirty years ago H. B. Dixon, in repeating Bunsen's experiments on the division of oxygen between carbon monoxide and hydrogen, both present in excess, discovered that a mixture of carbon monoxide and oxygen, dried by long contact with phosphoric anhydride, will not explode when sparked in the usual way in a eudiometer, whereas the presence of a trace of moisture or of any gas containing hydrogen (*e.g.*, methane, ammonia, or hydrogen chloride) at once renders the mixture explosive. These experiments, proving as they did the complexity of what at first sight would appear to be one of the simplest cases of combustion, opened up a new field of scientific investigation.

In 1883, H. B. Baker (working in Dixon's laboratory at Balliol College, Oxford) found that purified charcoal, when heated to redness in carefully dried oxygen, burns with extreme slowness and without flame—yielding principally the monoxide; the proportion of the dioxide formed varying inversely with the degree of dryness of the oxygen. In a further series of experiments he proved that highly purified sulphur or phosphorus may be repeatedly distilled in an apparatus filled with carefully dried oxygen, without any combustion whatever occurring, though the admission of even a trace of moisture at once causes a vivid burning. In subsequent investigations extending over a number of years, Baker has shown that a large number of gaseous interactions are either conditioned or greatly accelerated by the presence of moisture. Thus a dried mixture of hydrogen and chlorine does not explode on exposure to sunlight; dried ammonia and hydrogen chloride are mutually inert; and dried

electrolytic gas, free from hydrocarbon impurity, can be heated to redness without exploding.

The amount of moisture required to bring about such chemical changes as the above, is surprisingly small. E. W. Morley has estimated that the mere passing of a gas through a long column of phosphoric anhydride leaves only 3 milligrams of water vapour in a million litres (or rather less than 4 molecules of steam per 1000 million molecules of gas); and yet a much more prolonged drying is usually required to inhibit chemical action. Such facts as these, even if they do not raise doubts as to the adequacy of the usually accepted kinetic views of chemical processes, at least suggest the necessity of less stringent application of them.

The dependence of the combustion of carbon monoxide upon the presence of water vapour is well illustrated by H. B. Dixon's determination of the rates of explosion for mixtures of carbon monoxide and oxygen in combining proportions containing varying amounts of water vapour. Starting with a "well-dried" mixture, the rate of explosion increases with successive additions of moisture, from 1264 metres to a maximum of 1738 metres per second for mixtures saturated at 35°, any further addition of steam having a decidedly retarding influence, as follows:

Rates of Explosion, at 10° and 760 mm. for a Mixture $2CO + O_2$ *containing Varying Proportions of Steam.*

Hygroscopic Condition.	Per Cent. Moisture.	Rate. Metres per Second.
Well dried	—	1264
Saturated at 10°	1·2	1676
,, 20°	2·3	1703
,, 28°	3·7	1713
,, 35°	5·6	1738
,, 45°	9·5	1693
,, 55°	15·5	1666
,, 65°	24·6	1526
,, 75°	38·0	1266

Before entering upon a discussion of the theoretical aspects of the matter, certain other facts must be considered, namely:

1. In the detonation of a dried mixture of cyanogen with twice its own volume of oxygen the formation of carbon dioxide is complete. Moreover, under such conditions, it has been proved that carbon monoxide is primarily formed in the wave itself; the second stage of the combustion (namely, $2CO + O_2 = 2CO_2$) taking place in the rear of the wave.

2. A well-dried mixture of carbon monoxide (36 per cent.), ozone (8 per cent.), and oxygen cannot be fired with a powerful electric spark; also, on sparking a well-dried mixture of carbon monoxide (60 per cent.), chlorine peroxide (29 per cent.), and oxygen (11 per cent.), although a flame is propagated through the gases, as much as 76 per cent. of the original carbon monoxide may remain unburnt.

3. Dried carbon monoxide and oxygen completely combine without flame in contact with a heated platinum wire. Moreover, the writer recently proved that the most careful drying possible greatly accelerates the rate at which the gases combine in contact with a hot fire-clay surface at 500°.

4. There are certain well-established instances in which combustion is not determined by the presence of moisture—namely, the combustion of cyanogen, of carbon disulphide, and of hydrocarbons (ethane, ethylene, and acetylene).

Theories respecting the Function of Moisture.

1. H. B. Dixon has consistently maintained that, in the combustion of carbon monoxide, steam merely acts as the carrier of oxygen. He contends that in explosions the formation of carbon dioxide is always limited by its dissociation, and that at the highest temperature (*e.g.*, in the wave-front when the mixture $C_2N_2+2O_2$ is detonated) it is not formed at all by direct interaction of the monoxide and oxygen, because the internal energy which would thereby be imparted momentarily to the newly-born dioxide molecule, would bring about its dissolution. For the same reason flame is not propagated through a dried mixture of carbon monoxide and oxygen. But, if steam be present, the interaction of $CO + OH_2 = CO_2 + H_2$ would bring molecules of the dioxide into existence with a much less degree of internal agitation, and therefore capable of continued existence, while the hydrogen liberated would immediately combine with oxygen, forming steam, which is less easily dissociated than carbon dioxide. This explanation, while consistent with many of the facts connected with the combustion of carbon monoxide, cannot be extended to other well-known instances, and is particularly inapplicable to the case of hydrogen.

2. Mendelejeff, in his "Principles of Chemistry," ascribed the mutual inertness of carbon monoxide and oxygen to the circumstance that gases combine according to a supposed "law of equal volumes," or, in other words, that from the kinetic standpoint the primary changes in all cases must be considered as involving the collision of two molecules only. In the case of carbon monoxide he postulated the following cycle of changes:

$$\text{(i) } CO + OH_2 = CO_2 + H_2\text{; (ii) } H_2 + O_2 = H_2O_2\text{;}$$
$$\text{(iii) } CO + O_2H_2 = CO_2 + OH_2.$$

But, according to this supposed "law of equal volumes," a well-dried mixture of carbon monoxide and nitrous oxide, or of carbon monoxide and ozone, should be active, whereas Dixon has proved them to be as non-explosive as a dried mixture of the monoxide and oxygen.

3. H. E. Armstrong has always contended that chemical actions cannot occur between two perfectly pure substances, but require the conjunction of an electrolyte in order to form a closed conducting system. The presence of steam, which he supposes may always be regarded as rendered "conducting" by association with some traces of an electrolyte impurity, provides the necessary conditions for the passage of the current, the oxygen playing the part of depolarizer, thus:

On the other hand, H. B. Dixon has urged that a rate of explosion of nearly 1700 metres per second for a moist mixture of carbon monoxide and oxygen is incompatible with any interaction of the complexity thus postulated. There is doubtless *primâ facie* much force in this objection; but it is by no means fatal, seeing that the dimensions of the explosion wave are incomparably greater than molecular units, and the duration of chemical action, though extremely short when measured in terms of ordinary gross units of time, is at least many thousands of times greater than the intervals between successive molecular collisions.* A more serious objection to Armstrong's theory is the fact that there are well-established cases in which combustion apparently does not depend upon the presence of moisture.

4. In 1893 Sir J. J. Thomson pointed out that if the forces holding the atoms together in a molecule are electrical in character, the presence of drops of any liquid (such as water) of high specific inductive capacity would probably cause a sufficient loosening of the bands between the atoms to render the molecule much more reactive. He showed that the complete drying of a gas renders it non-conductive. H. B. Baker, in his "Wilde Lecture" before the Manchester Literary and Philosophical Society, described a number of new experiments which led him to tentatively put forward the theory that chemical interchanges in gaseous systems depend upon the presence of both "ions" and water vapour. The "ions" act as nuclei for the condensation of steam; and the liquid drops of water so formed, by virtue of their high specific inductive capacity, facilitate chemical change in the layer of gas immediately in contact with them. Chemists will await with the greatest interest the further development of this hypothesis. But the idea that such rapid changes as are met with in gaseous explosions are dependent upon the formation of aggregates of steam molecules in an atmosphere containing less than four of them per 1000 millions, and that such aggregates approximate to liquid drops at the high temperatures of flames, makes large demands upon the imagination; and it will require to be supported by the strongest experimental evidence.

Section V.—Combustion of Hydrocarbons.

The question of how a hydrocarbon is attacked by oxygen in combustion has been the subject of much controversy during the past twenty years; but it is only quite recently that experimental inquiry has been pushed far enough to justify the advancement of any complete theory of the process.

Throughout the greater part of last century it was accepted as an article of faith among chemists that hydrogen is the more combustible element of a hydrocarbon. Thus, as lately as 1884 H. B. Dixon, in his "Cantor Lectures" on "The Use of Coal Gas," speaking of the combustion of ethylene in its bearing on the luminosity of hydrocarbon flames, said: "This ethylene, when it is raised to a high temperature in contact with air, is decomposed; the hydrogen burning first and the carbon afterwards. There is a race for the oxygen of the air between the two constituents of the ethylene; and the hydrogen, being the fleeter of the two, gets to the oxygen first, and is burnt to water." Eight years later, when it was discovered in Dixon's laboratory that an equimolecular mixture of ethylene and oxygen yields on detonation almost exactly twice its own volume of carbon monoxide and hydrogen, in accordance with the empirical equation:

$$C_2H_4 + O_2 = 2CO + 2H_2,$$

and when also, about the same time, Smithells and Ingle, in their work on the "Structure and Chemistry of Flames," proved the presence of hydrogen in the interconal gases of aërated hydrocarbon flames, the dogma of the preferential combustion of hydrogen became untenable. Attempts were then made to revive an idea originally put forward by Kersten in 1861—namely, that "before any part of the hydrogen is burnt all the carbon is burnt to carbonic oxide, and that the excess of oxygen (if any) divides itself between the carbonic oxide and hydrogen." H. B. Dixon was himself inclined to this view; and Smithells spoke of the "preferential" burning of carbon both in his 1892 paper and in his lecture on "Flame" at the Nottingham meeting of the Association in 1893, although he has since disclaimed any intention of exalting it into a general doctrine.

The idea of a "selective" combustion, whether of carbon or of hydrogen, is, however, so repugnant to well-established principles that it could hardly be expected to meet with general acceptance in any final or complete sense, and there were many

* As the writer understands Dixon's objection to Armstrong's view, it is that while chemical action in the explosion wave may last a comparatively long time (*i.e.*, during many molecular collisions), and that therefore a quintuple molecular collision might happen in that period, it is impossible for the wave to be propagated as a sound-wave through quintuple collisions. Ordinary sound-waves may be many molecules thick, but they are propagated through bi-molecular collisions.

sceptics as to its validity. Moreover, while in the cases of acetylene and ethylene the assumption of a direct transition from the system $C_nH_m + \frac{n}{2}O_2$ to $nCO + \frac{m}{2}H_2$ implies a simple transaction from the kinetic standpoint, an extension of the idea to the cases of such hydrocarbons as propane or propylene would obviously raise serious difficulties,

$$2C_3H_8 + 3O_2 = 6CO + 8H_2,$$
$$2C_3H_6 + 3O_2 = 6CO + 6H_2.$$

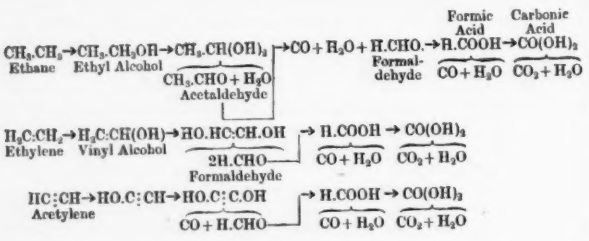
It therefore seemed necessary to consider whether the solution of the problem might not lie in the assumption of an initial association of the hydrocarbon and oxygen forming an unstable "oxygenated" or "hydroxylated" molecule, as suggested by H. E. Armstrong many years ago; and it was with some such possibility in view that the writer undertook the re-investigation of the subject about ten years ago.

Previous workers had confined their attention to combustion at such high temperatures as prevail in hydrocarbon flames and the explosion wave—conditions highly unfavourable to the detection or isolation of unstable intermediate "oxygenated" products, if such are really formed. It was therefore decided first of all to make a systematic study of hydrocarbon combustion at temperatures below the ignition points of the mixtures used, where the rate of oxidation would be much slower and more controllable, and the intermediate products more stable. The hydrocarbons selected for investigation were methane, ethane, ethylene, and acetylene; and at the outset of the work it was fortunately discovered that all four gases combine with oxygen at temperatures much below those at which either hydrogen or carbon monoxide begin to be oxidized with any appreciable velocity, or at which either carbon reduces steam or the reversible reaction $CO + OH_2 = CO_2 + H_2$ could have any influence whatever upon the result. Conditions were thus established which precluded the interference of secondary processes with the main line of change.

The first experimental method consisted in maintaining mixtures of each hydrocarbon with varying proportions of oxygen, sealed up in borosilicate glass bulbs of about 60 c.c. capacity, at known constant temperatures between 250° and 350°, for definite periods of time. Subsequently an apparatus was devised in which large volumes of the reacting mixtures could be circulated at a uniform speed in a closed system comprising (1) a surface of porous porcelain maintained at a constant temperature in a combustion furnace, (2) suitable cooling and washing arrangements for the removal of condensable or soluble intermediate products, (3) a mercurial manometer for recording pressures.

By means of these two experimental methods it was proved, as regards slow combustion—(1) that a hydrocarbon is ultimately burnt to a mixture of steam and oxides of carbon without any separation of carbon or liberation of hydrogen at any stage of the process; (2) that the oxidation is marked by a very large intermediate formation of aldehydic products; (3) that the fastest rates of oxidation are (in the cases of the four hydrocarbons examined) always obtained with a ratio of hydrocarbon to oxygen between 2 : 1 and 1 : 1 (an excess of oxygen above the equimolecular ratio always having a marked retarding influence); (4) that a large proportion of carbon dioxide is often found in the products under conditions which preclude all possibility of its formation either by the direct oxidation of the monoxide or by the interaction of the monoxide with steam.

Finally, the balance of evidence was so overwhelmingly in favour of the supposition that combustion had proceeded by successive stages of "hydroxylation" that the following schemes were put forward for the typical hydrocarbons ethane, ethylene, and acetylene:



In other words, the attack of the oxygen upon the hydrocarbon may be supposed to involve a series of successive "hydroxylations"—the hydroxylated molecules either breaking down or else undergoing further oxidation, according to their relative stabilities and affinities for oxygen at the particular temperature, substantially as represented by the above schemes.

It should be mentioned, however, that while in many of the "circulation" experiments a very large proportion of the intermediate aldehydic products were successfully removed from the sphere of action before undergoing further oxidation—*e.g.*, as much as 92 per cent. of the formaldehyde indicated at the third stage of the ethane scheme, and 45 per cent. of that required at the second stage of the ethylene scheme—in none of the experiments was it found possible to detect or isolate any of the monohydroxy derivatives which are, *ex hypothesi*, initially formed. This was perhaps hardly to be expected in the cases of ethylene or acetylene, where the monohydroxy derivative would be extremely unstable. In the case of ethylene, however, acetaldehyde (which is known to be readily formed by molecular rearrangement from vinyl alcohol) was isolated in certain experiments. But failure to detect the formation of ethyl alcohol during the slow oxidation of ethane did at first sight seem a serious obstacle to the acceptance of the "hydroxylation" theory. This difficulty was, however, largely removed when it was subsequently found that ethyl alcohol is oxidized at a much faster rate than is ethane under like conditions—a circumstance which seems to warrant the view that the effect of the initial "hydroxylation" of the hydrocarbon is to render the molecule much more susceptible to further attack. Finally, when Drugman, working in the writer's laboratory, obtained direct proof of the large formation of ethyl alcohol as the result of the interaction of ethane and ozone at 100°, the difficulty referred to entirely disappeared. Moreover there is strong indirect proof of the initial formation of monohydroxy derivatives during slow combustion in the fact that whereas the rates of oxidation observed with mixtures containing two molecules of hydrocarbon to one molecule of oxygen were hardly, if at all, inferior to those observed with equimolecular mixtures, the process was always much retarded by any further addition of oxygen beyond the equimolecular ratio. It may also be urged that the hydroxylation theory readily explains the large formation of carbon dioxide in the bulb experiments under conditions which would entirely preclude the idea of its formation by the direct oxidation of the monoxide or as the result of interaction of the monoxide with steam.

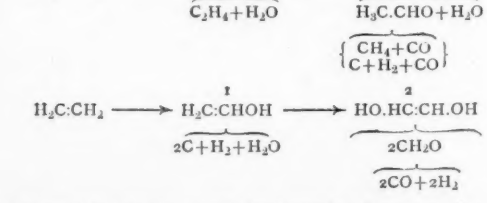
The next step in the inquiry was to ascertain whether the presence of moisture is essential to hydrocarbon combustion. A series of careful experiments on mixtures of the three typical hydrocarbons respectively with oxygen in equimolecular proportions thoroughly dried by long contact with redistilled phosphoric anhydride, under conditions which (as was proved) inhibited the formation of steam from electrolytic gas, gave wholly negative results. If anything, combustion occurred rather more readily with the dried gases than in the case of the corresponding experiments with undried mixtures. Therefore, while the conclusion finally advanced concerning the mechanism of hydrocarbon combustion agrees with the view originally put forward by H. E. Armstrong, in so far as the nature of the intermediate products is concerned, it differs from his in supposing that the oxygen is directly active.

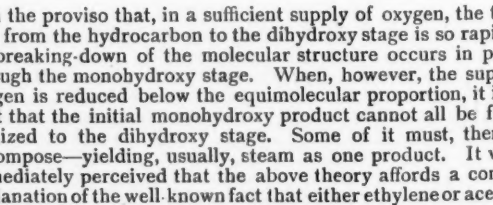
With the extension of the investigation to hydrocarbon flames and explosions, including "detonation" and explosions under high initial pressures, it became increasingly evident that the mechanism of combustion is essentially the same above as below the ignition point, in so far as the result of the initial molecular encounters between hydrocarbon and oxygen is concerned. At the higher temperatures of flames, secondary thermal decompositions undoubtedly come into operation at an earlier stage than in slow combustion; but they do not precede the onslaught of the oxygen on the hydrocarbon, as was formerly supposed, but arise in consequence of it.

In considering explosive combustion, therefore, it is necessary to take into account the possible modes of decomposition of the hydroxy derivatives formed in the first two stages of slow combustion, because these derivatives are so manifestly unstable at the high temperatures of flames that they would at once breakdown into simpler products. Ethyl alcohol, it is known, decomposes into ethylene and steam; acetaldehyde, into methane and carbon monoxide, or into carbon, hydrogen, methane, and carbon monoxide, according to the temperature; formaldehyde is resolved into carbon monoxide and hydrogen without the slightest separation of carbon. Thus:

Ethyl alcohol.	Acetaldehyde.	Formaldehyde.
$C_2H_5.OH$	$CH_3.CHO$	$H.CHO$
$C_2H_4 + H_2O$	$CH_4 + CO$; $C + 2H_2 + CO$	$CO + H_2$

Therefore taking as examples the typical cases of ethane and ethylene, the scheme for explosive combustion becomes





with the proviso that, in a sufficient supply of oxygen, the transition from the hydrocarbon to the dihydroxy stage is so rapid that no breaking-down of the molecular structure occurs in passing through the monohydroxy stage. When, however, the supply of oxygen is reduced below the equimolecular proportion, it is evident that the initial monohydroxy product cannot all be further oxidized to the dihydroxy stage. Some of it must, therefore, decompose—yielding, usually, steam as one product. It will be immediately perceived that the above theory affords a complete explanation of the well-known fact that either ethylene or acetylene on explosion with its own volume of oxygen yields carbon monoxide

and hydrogen, without any separation of carbon or steam formation, because in each case the principal intermediate product is formaldehyde, a substance which decomposes straight into carbon monoxide and hydrogen at high temperatures.

There are, moreover, two groups of facts relating to explosive combustion which, while they completely subvert the notion of a preferential combustion of carbon, harmonize very well with the new view of "hydroxylation." They are, briefly, as follows: (1) That whereas mixtures of olefines and oxygen corresponding to $C_n H_{2n} + \frac{n}{2}O_2$ behave on explosion like ethylene, inasmuch as they yield mainly carbon monoxide and hydrogen without any separation of carbon, similar mixtures of paraffins and oxygen—namely, $C_nH_{2n+2} + \frac{n}{2} O_2$—yield carbon, oxides of carbon, methane, hydrogen, and steam all in considerable quantities. (2) That, even in the case of an olefine, if the proportion of oxygen be reduced below that indicated by the expression $C_nH_{2n} + \frac{n}{2} O_2$, both carbon and steam are prominently formed.

In his presidential address to this section at the Leicester meeting in 1907, Smithells criticized the writer's interpretation of explosive combustion on the ground that "the isolation of an intermediate product under one set of circumstances is in itself no proof that this product is transitorily formed when the reaction is proceeding under another set of circumstances." To this criticism it may be replied: (1) That there is direct experimental proof of the formation of intermediate aldehydic products in hydrocarbon flames and explosions; (2) that notwithstanding the fact that the combustion of hydrocarbons has now been investigated over a range of temperature extending from that of incipient oxidation right up to the extreme conditions prevailing in detonation, no evidence has yet come to hand which warrants the assumption of any discontinuity in the immediate result of the initial encounter between hydrocarbon and oxygen molecules; and (3) that the theory of the intermediate formation of "hydroxylated" or "oxygenated" products furnishes a complete and sufficient explanation of the facts of hydrocarbon combustion as at present known—a requirement which no other alternative theory yet put forward is capable of satisfying. In this connection, the writer is glad to find some support in the recent Presidential Address of H. B. Dixon to the Chemical Society, where, speaking of the detonation of a mixture of equal volume of ethane and oxygen, he says: "The ethane is not burnt wholly to carbon monoxide and hydrogen, but appears to form (as Professor Bone has shown at lower temperatures) acetaldehyde and steam; the acetaldehyde yielding methane and carbon monoxide."

But to return to the consideration of facts: One of the most significant features of the writer's experiments has been the proof afforded of the relatively much greater affinity of hydrocarbons, as compared with that of either hydrogen or carbon monoxide, for oxygen at the high temperatures of flames. Thus when a mixture of acetylene and electrolytic gas corresponding to $C_2H_2+2H_2+O_2$ is exploded, there is absolutely no separation of carbon or formation of steam, and practically the same thing holds good in the case of a mixture of ethylene, hydrogen, and oxygen corresponding to $C_2H_4+H_2+O_2$. In each case the hydrocarbon is burnt to (ultimately) carbon monoxide and hydrogen, just as would be the case were no hydrogen originally present in the mixture. Recently the writer in an unpublished research on the division of oxygen between methane and hydrogen, in which mixtures corresponding to $CH_4+O_2+xH_2$ (x= 2, 4, 6, or 8) have been exploded at high initial pressures, has proved that with $x = 2$ upwards of 95 per cent. of the oxygen initially reacts with the hydrocarbon, and less than 5 per cent. of it goes to the hydrogen. Moreover, the proportion of the oxygen which goes to the hydrogen has been found to increase according to the second power of x, a circumstance which suggests that the combustion of hydrogen involves the trimolecular reaction $2H_2 + O_2 = 2H_2O$, and not the initial formation of hydrogen peroxide, as some have supposed. A similar series of experiments with mixtures $CH_4 + O_2 + xCO$ have proved that the affinity of carbon monoxide for oxygen is even less than that of hydrogen, and that the proportion of oxygen going to it increases as approximately the first power of x.

These observations have an important bearing on the chemistry of flames. Hitherto hydrogen has been considered as one of the most combustible of gases; but in reality it is very much less so than hydrocarbons. Indeed, so overwhelmingly great is the affinity of a hydrocarbon for oxygen, as compared with the affinities of either hydrogen or carbon monoxide or with its own tendency to decompose, that the initial stage of its combustion probably takes precedence of all other chemical phenomena in flames. This is certainly true of the propagation of flame through a homogeneous explosive mixture of hydrocarbon and oxygen. In the special case of a stream of hydrocarbon burning in air, partial decomposition may possibly occur in the innermost regions of the flame, where the supply of oxygen is very limited, before actual combustion begins. But in general, whenever the hydrocarbon and oxygen meet at high temperatures, their mutual affinities will prove superior to any disruptive force which might otherwise break-down the hydrocarbon. It is probably not so much the original hydrocarbon as its hydroxylated molecule that decomposes in ordinary flames. Be this, however, as it may, the experimental evidence does not warrant the view, so often encountered in scientific literature, that hydrocarbons are resolved into their elements prior to being burnt.*

Section VI.—Influence of Hot Surfaces on Combustion.

It is to the genius of Sir Humphry Davy that we owe the discovery of surface combustion. In his experiments on the ignition points of various gases, he had found (what is now a matter of common knowledge) that the constituents of a combustible mixture will combine with fair velocity at temperatures below the ignition point. This led him to ask the question whether, seeing that the temperatures of flames far exceed those at which solids become incandescent, a metallic wire can be maintained at incandescence by the slow combination of two gases without actual flame. He therefore tried the effect of introducing a warm platinum wire into a jar containing a mixture of coal gas and air rendered non-explosive by an excess of the combustible constituents. The wire immediately became red hot, and remained so until nearly the whole of the oxygen had disappeared. In subsequent experiments, Davy proved that hydrogen is far more susceptible to surface combustion than either ethylene or carbon monoxide; also, that the power of inducing surface combustion is by no means confined to the metals of the platinum group, which, however, exhibit it in an eminent degree.

In 1823 the subject was systematically investigated by Dulong and Thénard, and independently also by Döbereiner, who showed that all solids possess the power of accelerating combustion in varying degrees, according to their specific characters and fineness of division. Two years later William Henry observed that, when a platinum ball is immersed in a mixture of equal volumes of ethylene and electrolytic gas, the hydrogen and oxygen alone combine; no combustion of the hydrocarbon occurring unless the original mixture contains a much larger proportion of oxygen. This important result was confirmed by Graham in 1829.

Several explanations of surface combustion were put forward by these early investigators. Davy himself suggested an electrochemical one. "Supposing," he wrote, "oxygen and hydrogen to be in the relation of negative and positive, it is necessary to effect their combination that their electricities should be brought into equilibrium or discharged. This is done by the electrical spark or flame, which offers a conducting medium for this purpose, or by raising them to a temperature in which they become themselves conductors. Now platinum, palladium, and iridium are bodies very slightly positive with respect to oxygen. . . . They offer to the gases the conducting medium necessary for carrying off and bringing into equilibrium their electricities without any intervening energy, and accumulate the heat produced by this equilibrium." Döbereiner, who discovered that freshly prepared platinum black absorbs oxygen from the air, and that in this "oxygenated" condition it will cause steam to be formed on being plunged into a jar of hydrogen, contended that the metal merely acts as a carrier of oxygen. On the other hand, Fusinieri (1825) maintained that it is the combustible gas (hydrogen) only which is affected by the surface, being condensed and rendered extraordinarily active by association with the surface.

The matter formed the subject of a celebrated controversy between Faraday and De la Rive in 1834-35. De la Rive strongly upheld the view that surface combustion essentially consists of a series of rapidly alternating oxidations and reductions of the catalyzing material. Faraday, whilst not denying that finely divided platinum absorbs oxygen, argued with great force that true surface combustion involves an action quite distinct from that of an oxidized wire or foil upon a combustible gas. The function of the solid is, he contended, to condense both the oxygen and the combustible gas at the surface—thus producing a condition in the surface layer comparable to that of high pressure. After the year 1836, however, interest in the subject waned, and was not revived until quite recently.

It may here be remarked that heated surfaces have undoubtedly a marked influence in accelerating not only combustion but all chemical interchanges in gaseous systems. It is usually considered that the action of the surfaces is merely an accelerating and not a directive one at any particular temperature; and, although this may be generally true, it is not necessarily or universally so. But in regard to combustion, it may be assumed that, in general, the introduction of a hot surface will merely accelerate the process.

In the generation and applications of gaseous fuels, the technologist has to deal not only with combustion, and the interaction of the products of incomplete combustion, but also with decomposition and dissociation phenomena, and contact with hot surfaces accelerates all alike. Thus the influence of hot solids (in the shape of furnace walls and the like) assumes an importance which can hardly be over-estimated.

It will be generally agreed that the best means of elucidating the factors operative in surface combustion lies in determining the rates of combination of different gases with oxygen when the reacting mixtures are brought into contract with various solid surfaces at selected constant temperatures. This has been the line of attack usually adopted in recent investigations. But the method is only capable of yielding results of any value when the temperature selected is low enough to prevent the masking of the effects of surface combustion proper by changes in the main body of the gas which is not in contact with the surface at any given instant.

* No attempt has been made to discuss in any detail the experimental evidence on which the new theory of hydrocarbon combustion is based.

In interpreting the results of such velocity measurements the following possible factors must be considered—namely (1) the actual rate of combination at the surface, (2) the rates at which the reacting gases respectively diffuse inwards from the outside mixture on to the surface, (3) the rate at which the reaction product is removed from the surface, (4) the rates at which the reacting gases (or either of them) are rendered "active" by the surface, supposing the surface may act in some such manner, (5) changes (if any) in the physical texture of the surface itself.

It is obvious that, since any system in which a gaseous mixture is combining exclusively at the surface of a heated solid must be regarded as heterogeneous, the velocity of reaction will not be governed by its "order," as would probably be the case with a homogeneous system. Nevertheless several recent investigators —notably Bodenstein in his earlier experiments upon the non-explosive combination of electrolytic gas in contact with the walls of a glazed porcelain vessel—by overlooking this obvious consideration, have largely invalidated their conclusions.

Of the factors above enumerated, it is now generally agreed among competent observers that the actual rate of combination at the surface far exceeds either the rates of diffusion of the reacting gases on to the surface or the rates at which they are rendered "active" by the surface. This being so, it follows that the amount of change observed in the system in unit time will not be governed by the actual rate of combination at the surface, but by one or other of the remaining factors, whichever happens to be the slowest in its operation.

Nernst, who has recently advanced a general theory of reactions in heterogeneous systems, based on measurements of the rates of solution of salts in water, or of such substances as magnesia in acids, ignores (in the case of surface combustion) the possible "activation" of the gases by the surface, and contends that the velocity of surface combustion is governed by diffusion factors only. Bodenstein, in an entirely inconclusive series of experiments on the combination of hydrogen and oxygen in contact with platinum at the ordinary temperature, attempted to provide an experimental basis for the above theory; but it has been recently completely disproved by the researches of the writer and his pupils [R. V. Wheeler, G. W. Andrew, A. Forshaw, and H. Hartley], a first instalment only of which has so far been published. The following is a brief *résumé* of the principal results of these researches.

At an early stage of the research it became manifest that, in order to avoid errors inherent in a too restricted view of the phenomena, the action of a considerable variety of surfaces must be studied, including (1) such ordinary non-oxidizable metals as gold, silver, and platinum, (2) oxidizable metal, such as copper and nickel, (3) easily reducible oxides, as well as (4) non-reducible oxides of both basic and acidic character. Although the investigation has revealed certain minor differences between the action of the various surfaces, the results as a whole leave no room for doubt that the catalytic combustion depends primarily upon the condensation or absorption of one or other (and possibly both) of the reacting gases by the surface, whereby they are rendered "active." Any chemical explanation—such, for instance, as the supposition of a rapidly alternating series of oxidations and reductions of the catalyzing surface—is inconsistent with the numerous velocity measurements made during the research. Equally certain is it that the rate of combustion is governed, not by diffusion factors, as Nernst has supposed, but by the rate of "activation" of one of the reacting gases (usually the combustible gas) by the surface.

The catalyzing power of a new surface at a given temperature usually increases up to a steady maximum when successive charges of the reacting gases, mixed in their combining ratios, are circulated over it. After the attainment of this steady condition, the rate of combination is always directly proportional to the pressure, provided that the gases are present in their combining ratios and the product of combustion is rapidly removed from the sphere of action. Where, however, one or other of the reacting gases is present in excess, the rate of combustion is in nearly all cases proportional to the partial presence of the combustible gas (*e.g.*, hydrogen or carbonic oxide), which thus becomes the ruling factor. The behaviour of copper oxide towards mixtures of hydrogen with excess of oxygen, and of nickel oxide towards mixtures of carbon monoxide with excess of oxygen, have so far proved exceptional in this respect; the observed rates in both cases being more nearly proportional to the partial pressure of the oxygen than to that of the combustible gas. In the case of copper oxide there is definite proof of the formation of a condensed film of "active" oxygen at the surface, which actually burns up the hydrogen before it can reach the still more active oxygen chemically combined with the copper.

The catalyzing powers of all the metallic and non-reducible oxide surfaces examined are highly stimulated by previous exposure to the combustible gas, which is undoubtedly rendered "active" by association with the surface. This stimulus is usually very durable; but in most cases it is at once destroyed by a short exposure to oxygen. Although as a general rule oxygen has *per se* no stimulating effect on a catalyzing surface, cases to the contrary have been encountered. But even in these exceptional instances the effect is neither so marked nor so durable as the corresponding effects always observed in respect of the combustible gas.

One notable feature with regard to the catalytic combustion of carbon monoxide over a fireclay surface is the fact that the rate of combustion of a mixture of $2CO+O_2$ at 500° is about doubled by a thorough drying of the gases; the "reaction constant" increasing from about 0·09 to about 0·20. This remarkable result can hardly be explained on the supposition that, in the case of the undried mixture (saturated at 18°), steam acts merely as a diluent. It apparently exercises a specific retarding influence out of all proportion to its relative mass.

Of scarcely less interest are some recent results bearing upon the effects of a hot fireclay surface (at 500°) upon the relative rates of combustion of methane, hydrogen, and carbon monoxide. In the previous section attention was directed to the fact that in ordinary explosive combustion the affinities of methane and other hydrocarbons far exceed those either of hydrogen or of carbon monoxide for oxygen. In contact with a hot surface, however, the order is completely reversed, owing to an apparently selective action of the surface in rendering the combustible gases active. This circumstance is sufficient to invalidate the conclusions of certain earlier investigators, notably those of Landolt, concerning the relative combustibilities of various gases, owing to their having sucked off the products of partial combustion from the inner regions of coal-gas flames through platinum tubes and the like. It may be taken for granted that the introduction of a hot solid into a mixture of burning gases is in itself sufficient to upset the regular conditions of explosive combustion.

The conclusions drawn by Bone and Wheeler as to the catalytic combustion of hydrogen derive collateral support from the recent researches of Sabatier and Senderens on the remarkable powers of many metallic surfaces (and especially nickel) of rendering this gas "active" at comparatively low temperatures. In illustration of their results may be quoted the following remarkable instances of direct "hydrogenations" effected by merely passing a mixture of the substance in question with hydrogen over finely divided and freshly reduced nickel. In this way olefinic hydrocarbons are convertible into the corresponding paraffins at 160°; benzene yields cyclo-hexane; nitro-benzene may be reduced to aniline; while nitro-methane is convertible into methylamine at 150° to 180°, and into methane and ammonia at 350°. Finally, a mixture of carbon monoxide (1 volume) and hydrogen (3 volumes) may be completely transformed into methane and steam at 250°.

In the present imperfect state of our knowledge, any suggestion which may be put forward as to the action of hot surfaces in rendering such gases as hydrogen or carbon monoxide "active" must be considered as quite tentative. Several facts, however, point to a possible connection between surface combustion and the emission of charged particles by hot solids. In 1903, H. A. Wilson discovered that hydrogen has an enormous influence upon the negative leakage from a clean platinum wire at high temperatures. Thus at 135° for a given potential difference, the leakage in hydrogen at 0·014 mm. pressure was found to be no less than 25,000 times greater than in air. It was also proportional to the pressure and depended upon the hydrogen actually occluded by the metal. These observations have since been confirmed by O. W. Richardson, who, however, finds that the leakage consists of two parts, one proportional to the pressure (due to ionization by collisions), the other quite independent of it. He takes the view that hydrogen does not act *per se*, but only indirectly by producing some change in the surface of the metal. Sir J. J. Thomson has found that the rate of emission of negative corpuscles by alkali metals at ordinary temperatures is greatly increased while they are absorbing hydrogen. F. Horton has proved that the negative leakage from hot lime is much greater in hydrogen than in air. With regard to the catalytic combustion of hydrogen in contact with metallic surfaces P. J. Kirkby, when experimenting upon the effects of electrically heating a platinum wire to *circa* 275° in electrolytic gas at pressures under 40 mm., concluded that it is "probably connected with the corpuscular discharge which is known to be emitted by platinum." Finally, it has recently been proved in the writer's laboratory that gold gauze immediately acquires a negative charge on its inducing the surface combustion of either hydrogen or carbon monoxide.

All these facts point to the necessity of a systematic investigation of the electrical condition of heated surfaces during catalytic combustions as a preliminary to a better understanding of the phenomenon.

Reinforced Concrete for Engineering Structures.

We have received from the Council of the Institution of Civil Engineers a copy of the preliminary report upon the inquiry undertaken by the Institution into the conditions of the employment of reinforced concrete in engineering structures. It deals entirely with facts and information relating to experience with this material up to the present time; the Committee charged with the inquiry being now engaged upon tests and investigations with a view to enlarge the knowledge which has been already gained, and to formulate views by engineers bearing upon the employment of reinforced concrete. The contents include a "Summary of Various Systems of Reinforced Concrete," "Experimental Data in regard to Beams and Columns," and "Experimental Data bearing upon the Properties of Materials Employed in Reinforced Concrete," by Mr. E. W. Hollingworth; a "Summary of Rules for the Use of Reinforced Concrete in Various Countries," by Mr. C. F. Marsh; a full report of the evidence and information given on special points of the Committee's inquiry; and reports on works executed. Following these matters are a useful bibliography and an index.

THE DOHERTY PROCESS FOR TREATING COMBUSTIBLE GASES.

Rather more than twelve months ago, letters patent for the United States were granted to Mr. H. L. Doherty, of New York, for a process for treating combustible gases. The invention, as set forth in the opening words of the specification, "consists of a method of treating combustible gases (such as blast-furnace gases and what is known as Mond gas), containing an appreciable amount of carbon dioxide, by preheating the gas to a temperature sufficient to supply the heat required for the dissociation of the carbon dioxide, or to a temperature as near to such temperature as is practicable, and then passing the preheated gas through the fuel bed of a down-draught producer, whereby the contained carbon dioxide is reduced to carbon monoxide, with the production of a gas nearly free from carbon dioxide, and which is particularly suitable for use in gas-engine and high-temperature work." Mr. Doherty has applied for an English patent (No. 7786 of the present year); but the specification has not yet been issued. The following particulars of the invention are therefore taken from the American publication.

As is well known, the presence of any large amount of carbon dioxide in a combustible gas reduces, to a very appreciable extent, the flame temperature obtainable in the combustion of that gas. This is due to the fact that part of the heat developed must go to raising the temperature of the inert and useless carbon dioxide. As the specific heat of carbon dioxide per unit volume is high, this means that the heat available for raising the temperature of the necessary elements of the combustion is materially reduced. Besides, carbon dioxide has a specific retarding action on the combustion itself; rendering it slow, and producing a slow-burning diffused flame of large volume, instead of the concentrated intense flame produced by a rich gas free from carbon dioxide when burnt by an adequate supply of air.

When a furnace gas is burnt to generate steam, in the manner in which it is generally utilized, the carbon dioxide, which is always present, has the effect of decidedly reducing the efficiency of the combustion. As explained above, it acts to render the combustion sluggish and diffused. The result is that the gases come into contact with the comparatively cool tubes of the boiler before the gas has been thoroughly burnt; and their temperature is in this way quickly reduced below that necessary to maintain combustion. The result is that the flue gases generally show a considerable amount of unburnt carbon monoxide. In the case of so-called Mond gas, which is a gas made by the use of a large amount of water in the producer, the effects of its carbon dioxide are similar, though the high content of hydrogen renders them less noticeable.

The average composition of an iron blast-furnace gas is about as follows: Carbon monoxide, 23 per cent.; carbon dioxide, 12 per cent.; methane, 2 per cent.; hydrogen, 2 per cent.; water vapour, 3 per cent.; nitrogen, 58 per cent. Mond gas has an average composition as follows: Carbon monoxide, 16 per cent.; carbon dioxide, 12·4 per cent.; methane, 2·2 per cent.; hydrogen, 24 per cent.; nitrogen, 45·4 per cent. The analysis given of the Mond gas is for the cooled gas, which is therefore comparatively free from water vapour. Since this gas is invariably cooled before leaving the producer apparatus for the purpose of recovering the ammonia which it carries, while the blast-furnace gas, when used to fire boilers, is always used hot, the comparison of cold Mond gas with hot blast-furnace gas is a perfectly fair one.

From the facts mentioned above, we can see that the efficiency of the utilization of these gases could be greatly improved by even the simple removal of the high proportion of carbon dioxide. By this invention, however, instead of removing the carbon dioxide, it is decomposed in contact with carbon at a high temperature, forming two molecules of carbon monoxide for every molecule of carbon dioxide; thus actually enriching the gas, and at the same time appreciably increasing its volume, as well as eliminating the carbon dioxide to a large extent.

In the accompanying illustrations, fig. 1 is a section of an apparatus suitable for applying the invention, taken on a plane through the lines A B of fig. 5, A^1 B^1 of fig. 3, and A^{11} B^{11} of fig. 4. Fig. 2 is a section through a recuperator, which is functionally connected with the gas-producer proper, taken on a plane through the line C D of fig. 5. Fig. 3 is a cross-section through the superheater on the line E F of fig. 5 and E^1 F^1 of fig. 1. Fig. 4 is a cross-section through the recuperator, which is functionally connected with the enriching producer, on a plane through the line G H of fig. 5 and G^1 H^1 of fig. 1. Fig. 5 is a diagrammatic plan of the entire apparatus.

The method of operation is as follows: Air enters the bottom flues of the recuperator A (fig. 5) through the dampers B, which regulate the volume and distribution of the air. Passing through the air-flues of the recuperator, the air comes into contact with a layer of water, which is maintained in the necessary number of flues to ensure proper saturation of the current. The hot gas from the producer passes through the gas-flues, enveloping the air-flues; its direction of flow being parallel, but opposite in direction, to the current of air. The greater part of the sensible heat which the gas carries out of the producer is thus returned to the latter in the heated air and water vapour. The hot air water vapour current, after leaving the recuperator, is introduced, in the usual type, into the lower part of the gas producer C, through the pipe D. Passing upwards through the fuel bed in the producer, the oxygen and part of the water of the air current react with the fuel therein and form Mond gas in the ordinary way. This gas passes off from the producer through the pipe E, and thence through the gas-flues of the recuperator.

The air-flues F in the recuperator consist of a number of horizontal sections joined alternately front and back with the adjacent flues above and below, so as to form a continuous return-bend flue. As shown in fig. 2, the recuperator has three such flues; but it is obvious that the number may be either increased or diminished without departing from the principle involved. The air-flues are located in, and enveloped by, three larger parallel flues G. These flues consist of horizontal sections joined alternately front and back, so as to form continuous return-bend

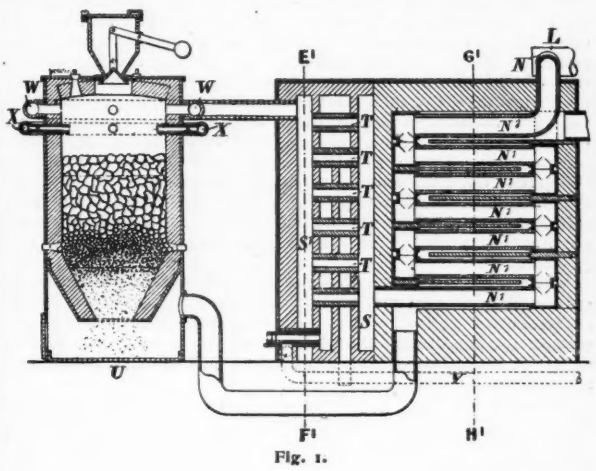


Fig. 1.

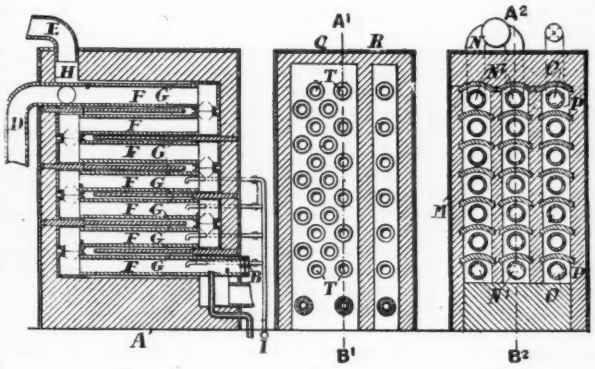


Fig. 2. Fig. 3. Fig. 4.

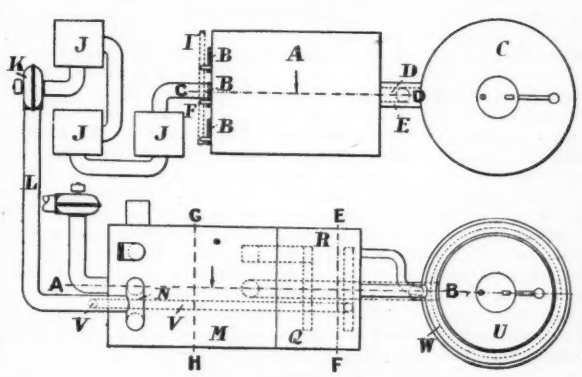


Fig. 5.

flues. The hot gas from the producer enters the recuperator through the pipe E, and is distributed to the flues G by the cross flue H. The hot gas passes through the flues G, and gives up most of its sensible heat to the air passing through the flues F. The air enters the recuperator through dampers shown, passes through the flues F of the recuperator, and thence to the producer. The recuperator has a water-supply pipe I, with connections, into the lower sections of the flues F. Valves control the flow of water to the air-flues.

In order to maintain as high a temperature differential as possible between the air and gas currents, it is desirable to secure the evaporation of the water as low down in the recuperator as

possible. For this reason the patentee introduces the water to the air-flues at such a point that the air passing through the flues is loaded with the proper quantity of water. All the water evaporated in each flue is preferably run into the uppermost water-pan in use, and the pans below are supplied by the overflow from this. Dams in the flues, having water connections, ensure the maintenance of a shallow layer of water in the flues, and thus form water-pans of the bottom of the sections. If the amount of evaporation is lower than is required, water is admitted to a section higher up in the recuperator. Drain pipes are provided to carry away any excess of water from the lower flues.

The cooled Mond gas leaving the recuperator passes to the ordinary scrubbing towers J, where the ammonia is removed from the gas. These towers do not necessarily differ from those at present in use. From the last tower the gas is withdrawn by the exhauster K, and forced through the pipe L to the recuperator M. This is in reality two separate recuperators, one for air and the other for gas, built side by side, within the same shell. The section shown in fig. 1 is through one of the gas-flues; but the construction is identical on the air side. N (fig. 4) is a cross connection between the two gas-flues N^1, so that the gas flowing through N is divided between the flues M, which are made up of horizontal sections, each connected alternately, front and back, with the vertically adjacent flues, in order to form continuous return-bend flues. Enveloping these flues are return bend flues for the enriched gas. The latter flues are formed by introducing staggered, horizontal baffle walls in the recuperator, so as to make the gaseous current passing through the return bend flues take a path parallel, but in the opposite direction, to the current passing through N^1. O is the air-flue, while P is the enveloping gas-flue.

When the gas to be treated contains only such a proportion of carbon dioxide that the preliminary superheating of the gas is sufficient to furnish the heat requisite for the dissociation of the carbon dioxide, the addition of air to the gas is omitted. In this case the secondary air recuperator as well as the superheater are omitted.

The cold Mond gas and air passing through the recuperator go next to their respective superheaters Q R (fig. 5). These are built within the same shell, but are so arranged that there is no communication between the gas and air sides. On passing from the recuperator, the gas enters a flue extending across the full interior width of the superheater, establishing communication with the small flues shown. They are simply fire-clay flues, of small interior diameter, piercing the walls of the superheater, and also the baffle wall, and establishing communication between S and the similar flue S^1. The gas entering S passes through the flues T into the flue S^1, thence out through the pipe shown to the gas-pipe of the enriching producer. The air passes in similar manner through the flues of the air superheater to the air-pipe of the producer U (fig. 5). V is a pipe tapped into the pipe L, and diverting a portion of the Mond gas to the burners of the superheaters, which have an air passage with a damper regulating the admission of air. Surrounding the air passage is an annular one for the gas. The air and gas mix and burn on their entrance to the combustion flue; the hot products of combustion passing upward around the flues T, over the baffle wall down through the flues to the hot gas flue of the air recuperator, and thence to the stack. The burners are connected by a cross flue, so that they are all supplied with gas by the pipe V. Gates or dampers control the supply of gas to the burners.

The enriching producer may be of any type suitable for operation with downdraught in the manner hereafter explained. In the apparatus shown, the producer has a metal shell, suitably lined with refractory material, and having a refractory roof or arch to the fuel chamber. Suitable pokeholes are arranged for giving access to the interior of the producer; and a charging device is provided for putting in the fuel. The highly heated Mond gas to be treated (enriched) is introduced into the upper part of the fuel chamber through the pipe W and connections; and the heated air usually necessary to maintain the reaction in the producer is admitted through the pipe X and connections—the inner portions of the latter being of refractory material. The temperature in the fuel chamber being maintained at a high point, a portion of the Mond gas is burnt by the oxygen of the air, with the probable formation of water vapour and carbon monoxide. Owing to the high proportion of hydrogen in the Mond gas, and the high velocity of the reaction between this element and oxygen, it is probable that the oxygen of the air introduced burns principally according to the reaction—

$$(1)\ 2H_2 + O_2 = 2H_2O,$$

rather than according to the reaction—

$$(2)\ 2CO + O_2 = 2CO_2.$$

Since the products of these combustions are dissociated again in the fuel bed of the producer, by the respective reactions—

$$(3)\ 2H_2O + C_2 = 2H_2 + 2CO$$
$$(4)\ 2CO_2 + C_2 = 4CO,$$

the net heat developed is the same in each case, since it is that due to the burning of equal weights of carbon to carbon monoxide. It is therefore a matter of indifference which reaction predominates.

The gases from the upper combustion chamber of the producer, carrying the carbon dioxide introduced with the Mond or blast-furnace gas and the water vapour and carbon dioxide produced by the combustion in the upper part pass downwards and into the fuel bed, where the highly incandescent carbon reacts with the water vapour and carbon dioxide, according to reactions (3) and (4). In the case of the water vapour and carbon monoxide formed from the partial combustion of the gas, they have, in the combustion itself, furnished enough heat for their subsequent dissociation. Moreover, owing to the fact that the oxygen of the water and half of that of the carbon dioxide burns a portion of the fuel to carbon monoxide, the net result of the combustion of the hydrogen and carbon monoxide and their subsequent dissociation is to liberate an amount of heat equal to that formed by the burning of the weight of carbon with which they react to carbon monoxide. This is the heat which serves to dissociate the carbon dioxide originally present in the untreated gas. Since the carbon dioxide requires theoretically about 1600 B.Th.U. per pound of carbon dioxide so dissociated, and the net amount of heat theoretically liberated in the combustion of the portion of the gas burnt in the upper part of the producer is about 3280 B.Th.U. per pound of oxygen reacting, there is required theoretically to maintain the fuel bed of the enriching producer $1600 \div 3280 = 0{\cdot}488$, or (say) $\frac{1}{2}$ lb. of oxygen for every pound of carbon dioxide introduced with the gas. This is on the assumption that the air and gas enter the producer at the temperature of the fuel bed therein—say at 1700° to 1800° Fahr. By the preferred method of treatment which the patentee has revealed in his specification, he introduces the gas and air at the highest practicable temperature—say about 2500° Fahr. By this device, at the expense of burning a small quantity of the untreated Mond gas, he supplies to the gaseous currents, previous to their introduction into the producer, about 65 per cent. of the heat necessary for the dissociation of the carbon dioxide of the gas. As a result, he has reduced the theoretical amount of air necessary to maintain the temperature in the producer to that corresponding to $\frac{1}{2}$ lb. of oxygen per pound of carbon dioxide, or (say) 1 lb. of air per pound of carbon dioxide originally present in the gas. This would correspond to about 0·20 cubic foot of air per cubic foot of Mond gas. In order to meet the various radiation and conduction losses, however, it is necessary in practice to use at least 0·25 cubic foot of air per cubic foot of Mond gas when they are introduced into the producer at the given temperature—*i.e.*, 2500° Fahr. With gases which contain less carbon dioxide than Mond gas of normal composition, the quantity of air used in the enriching producer may be correspondingly lessened. When the carbon dioxide of the gas is comparatively low, it becomes possible to cut out the auxiliary air entirely, and maintain the reactions in the enriching producer entirely by the self-contained heat of the highly superheated gas.

The cooling of the crude gas, after it leaves the producer in which it was made, should, where practicable, be carried on below 212° Fahr., so as to condense and remove from the gas all the steam or water possible. The presence of steam in the gaseous current introduced into the enriching producer is in the highest degree objectionable, and the patentee says it is to be avoided to the greatest possible extent. Using the proportions of air and gas given, the finished gas would have about the following composition: Carbon dioxide, 2·05 per cent.; carbon monoxide, 27·2 per cent.; hydrogen, 19·65 per cent.; methane, 1·8 per cent.; nitrogen, 49·3 per cent. The gas would at the same time be increased in volume by about 20 per cent., and the calorific power per cubic foot by about 10 to 12 per cent.

One of the difficulties heretofore encountered in the enrichment of gases containing carbon dioxide has been that, owing to the necessity of introducing air into or with the gas to maintain the temperature in the fuel bed of the secondary or enriching producer at a reacting temperature, part of the gas was, of necessity, burnt in the lower part of the fuel bed, with the production of a high temperature at the zone where the ratio of ash to fuel is high, and the consequent fusion of the ash formed. In addition, where the heat developed by the combustion of the oxygen of the air admitted to the producer has alone been relied upon to maintain the temperature of the fuel bed, the large amount of nitrogen that must of necessity be introduced with the air results in a treated gas having a calorific value no higher than, if as high as, the original gas.

The Patentee's Explanation of his Invention.

The specification ends with the following remarks by the patentee upon the process described.

In my improved method which I have herein revealed and claimed, I make no attempt to accomplish what is in fact impracticable—*i.e.*, the simultaneous introduction into a bed of ignited fuel of a combustible gas containing an appreciable amount of carbon dioxide and the air necessary for the generation of sufficient heat to balance the endothermic reaction which takes place with the carbon dioxide of the combustible gas, without burning part of the combustible constituents of such gas. In my method, it is a matter of indifference whether the heat for maintaining the dissociating reactions is generated by the combustion of part of the gas itself or the carbon of the fuel bed, since the net thermal result is the same in either case. In my method, it is true, I develop as high, or even higher, temperature in the reductor or secondary producer at the point of introduction of the gas and air; but I do so under conditions which cause the local high temperature to facilitate the operation of the producer rather than retard the same. By introducing the gas and air at the upper surface of the fuel bed, the local high temperature developed

becomes an advantage. By this device, the freshly charged fuel is immediately subjected to a temperature which quickly distils off its volatile constituents, which must of necessity pass through the whole depth of the fuel bed. The result is that the tarry vapours are wholly broken-down into permanent gases, which add greatly to the illuminating and calorific power of the gas when a bituminous coal is used in the reductor. It has heretofore been found very difficult to make use of bituminous coal, owing to the difficulties caused by the tarry substances carried in suspension in the gas.

In the proposed methods of treating blast-furnace gas for the reduction of its carbon dioxide, the difficulties mentioned as following on the local high temperature caused by the combustion between the crude gas and the admixed air are not due to the high temperature of itself, but to the local development of such high temperature in the ash zone of the producer. In the unburnt fuel, the mineral matter which constitutes the ash occurs, for the most part, in very small particles, disseminated throughout the carbonaceous matter of the fuel. These particles are not in contact with each other, but are, so to speak, separated or insulated from each other by the surrounding particles of carbonaceous matter. In such a position, it is immaterial to how high a heat they may be subjected, since they are isolated from one another. They may be more or less completely fused without the least danger of them agglomerating together to form clinker or slag. If, then, we introduce the combustible gas containing carbon dioxide, and the air required to thermally balance its reaction with the carbon of the fuel, in contact with the unburnt fuel, instead of in contact with the ash, it is a matter of indifference how high a temperature is produced. The temperature may be as high as it will, and yet not cause sintering or clinkering of the ash. With a sufficient depth of fuel, there is, practically speaking, no danger of the high temperature of the hottest layers of the fuel bed extending to the ash zone of the reductor; for the water vapour or carbon dioxide formed by the combustion mentioned, in its passage through the fuel bed, is again dissociated with the absorption of heat. There is, therefore, progressive diminution of temperature from top to bottom of the fuel bed. The heat developed, due to the reaction of the gas and air, takes place in immediate contact with the part of the fuel bed the potential re-active energy of which is the greatest. The higher the temperature at which the gases come into contact with the fuel, the greater will be the speed and energy of the endothermic reaction taking place in the upper part of the fuel bed. There is thus secured automatic regulation of the working of the reductor or producer; for, as stated, the development of excessive temperature in any part of the fuel bed is immediately checked by the increased dissociation of the endothermically reacting constituent of the gas. On the other hand, if the temperature at any point tends to fall too low, the diminished dissociation of the carbon dioxide at that point lessens the heat abstracted from the fuel bed at that point, and permits it to recover its normal temperature. This self-balancing action of the exothermic and endothermic reactions has a tendency to keep a much greater depth of the fuel bed at a reactive temperature than is the case in ordinary practice. With any given proportion of air and gas and a given rate at which they are passed through the fuel bed, there is thus a tendency to establish a definite temperature and downward temperature graduation in the mass of fuel. By properly regulating the proportion of air to gas, and the velocity at which the current is forced through the fuel bed, it is possible to maintain the temperature conditions in the producer at any desired point.

The high temperature in the upper part of the fuel bed has an incidental advantage which considerably facilitates the operation of the enriching producer or reductor. The result of the high temperature is that the ash particles are fused within their carbonaceous envelope. As the burning fuel sinks through the shaft of the producer, it is becoming continually cooler and cooler, until, by the time the carbonaceous envelope of the ash particles has been burnt away, it has reached a temperature below the fusing-point of the ash. The result is that the ash, instead of consisting of half-fused masses of clinker, is of a decidedly sandy or granular nature, which greatly facilitates its removal from the producer, as well as keeps the ash bed in an open, porous condition. By introducing an efficient recuperator and evaporator between the Mond producer (where the crude gas is Mond gas instead of blast-furnace gas) and the absorption towers, I am able to restore to the Mond producer a much larger proportion of the heat carried out of it by the gas than can be done in the ordinary method of working. Besides, the additional heat recovered enables me to dissociate more water in the producer, with the result of producing a richer gas.

Scope of the Invention.

While in the foregoing description I have selected for the purpose of illustrating my invention its specific application to Mond gas, it is evident that the process may be applied to the treatment of any combustible gas containing reducible quantities of carbon dioxide—that is, quantities sufficiently large to permit a useful amount of reduction by contact with hot carbon. Where, as in the case of the treatment of blast-furnace gas, the volume of gas is very large, it is often advisable to use several reductor producers rather than a single one for treating the gas. When this is done, I may either pass the gas through the producers in parallel (to borrow an electrical term) or in series, as may seem most desirable.

A great advantage of my method is that I am enabled to use in the producer bituminous coals instead of coke or anthracite. The high temperature in the upper part of the fuel bed, and the fact that the products of distillation must, of necessity, pass through the whole mass of incandescent fuel, ensure a perfect breaking-down of the hydrocarbon vapours into permanent gases; thus avoiding any trouble due to the tarry vapours that are ordinarily found in the gas when bituminous coals are used. Owing to the fact that I can make use of bituminous coal, I obtain a gas having a much higher illuminating value than ordinary producer gas. Where the gas is to be used for firing furnaces—such as reheating furnaces, for example—this feature of my invention is of very great importance. The hydrocarbons of the coal have a practical enriching value far in excess of the actual increase which they cause in the calorific value of the gas. This is due to the fact that they cause the gas to burn with a flaming effect, which, by increasing the radiant effect of the combustion, greatly increases the quantity of heat that is transmitted to the charge in the furnace.

HORIZONTAL RETORT RESULTS AT STUTTGART.

Most of the carbonizing results from German gas-works to which attention has recently been called relate to vertical retorts or large carbonizing chambers; and it is a welcome change to find that one German gas manager at least—Herr Göhrum, of Stuttgart—still has confidence in the value of horizontal retorts. He has published in the "Journal für Gasbeleuchtung" for the 27th ult. the results obtained at the Stuttgart Gas-Works with a new and up-to-date installation of horizontal retorts; and some particulars are worth quoting from his communication for comparison with the data furnished by other German gas-works for carbonizing plants of other types.

The new retort-house at Stuttgart has been equipped since June, 1909, with 22 settings of nine horizontal retorts, 6 metres (19·7 feet) in length, having the producers on one side. The retorts are charged and discharged by De Brouwer machines, and the coke is handled by Illig's apparatus. They are elliptical in cross section, 400 mm. by 600 mm., or (say) 15·7 in. by 23·6 in. because experience has shown that this shape is well adapted for the use of projecting and expelling stoking machines. There are ascension-pipes on the charging side only of the bench; and the hydraulic main is placed about 6 ft. 6 in. above the crowns of the settings, because previous trials have demonstrated that thick tar does not form in it in these conditions. The tar produced is of a thin and freely fluid character. No sagging of the retorts has taken place. They are charged, at intervals of nine hours, with an average charge of 6½ metric tons (128 cwt.). Six-hour charges have been given up because it was found better in respect of avoidance of the formation of scurf, and economy of labour, to adopt full charges and a longer period for working them off. No stop-plate is used at the discharging end of the retort, but a small portion of the previous block of coke is allowed to remain to serve as a stop. The retorts are charged as full as possible, and the charges are completely worked off in the nine hours. The average make of gas per ton of coal, from Dec. 1 to the present time, has been 11,698 cubic feet.

The whole of the coal supplied to the retort-house passes over an automatic weighing-machine, which is checked once a week. The coal used was taken for the most part from store, and some of it had been standing in the open for a year-and-a-half. It consisted chiefly of English coals. The old settings of horizontal retorts, 9 ft. 9 in. long, had afforded a make of less than 10,765 cubic feet per ton, partly owing to their lower heats. The length of the retort does not affect the make of gas when De Brouwer charging-machines are used, provided the speed of the projecting band is regulated accordingly. The gas had an average net calorific power of about 560 B.Th.U. per cubic foot. The amounts of tar and ammonia produced varied with the kind of coal used. The average make per setting per diem (including time spent in scurfing) was 155,390 cubic feet, which corresponds to about 164 cubic feet per diem per square foot of ground area covered by the retort-house. The coke consumed in the producers was 13 to 14 per cent. of the weight of coal carbonized, or 24·3 lbs. to 26·8 lbs. per 1000 cubic feet of gas made.

The coke obtained from all kinds of coal is large and firm; and it may be noted that, by the mode of quenching adopted, it reaches the breaking and screening plant in a dry condition. The stoking machinery is overhauled daily by a man who is in charge also of the other electro-motors on the works; and the costs of repairs are very low. The parts requiring most frequent renewal are the head of the ram of the discharging-machine, which lasts rather more than one year, and the band of the charging-machine, the life of which is about half-a-year. The labour required, including mechanics, clinkering, and looking after the coke-conveyor, is seven men for eight settings with eight-hour shifts. The greater labour required in comparison with vertical retorts and chamber settings is, the author says, balanced financially by the lower charges for depreciation and interest and the smaller fuel consumption. He considers that through horizontal retorts, equipped in the manner described, can compete successfully with all modern systems of carbonization so far tried.

CORRESPONDENCE.

[We are not responsible for opinions expressed by Correspondents.]

High-Pressure Gas Lighting for Textile Mills.

SIR,—I was very much interested in the extracts from Mr. Walton's valuable paper on "High-Pressure Gas Lighting for Textile Mills" in the last number of the "JOURNAL," and enclose a schedule of actual costs of mill lighting by various systems which may be of interest to your readers. These figures were obtained by me for use in a discussion which took place in February, 1908, between the members of the Manchester and District Junior Gas Association and the Manchester District Students' Section of the Institution of Electrical Engineers. The figures relate to cotton-spinning mills in the Oldham district; and they were in every case supplied by the managers or secretaries of the mills concerned. In the cases of electric lighting, the mill engines were indicated when driving with and without the dynamo running. The lamps used were all carbon filament, as at that time the osram and tantalum lamps, when tried, proved to be too fragile to stand the vibration of a textile factory. The mantle renewals in mill No. 7 (low pressure) were very excessive, and lead one to think that very inferior mantles must have been used. I would just mention that in the case of gas lighting the costs of installations include services from corporation mains, meters (except No. 6), all piping, burners, cocks, &c., as well as compressing plant for the high-pressure installations. Mr. Walton's figures of 598 to 612 hours' lighting per year are very high compared with those given to me, and which, I was informed, were in all these cases carefully recorded.

I should like to express my appreciation of Mr. Walton's paper, as undoubtedly a good deal of ignorance prevails among mill managers and directors respecting the saving (?) they are effecting by the provision of generating plant, &c., for the purpose of electrically lighting their mills. In many cases of which I have personal knowledge, it only requires a few years' experience to convince such gentlemen that they are most efficiently and economically served by incandescent gas lighting, even when used in low-pressure burners.

JAS. TAYLOR, Engineer and Manager.

Hollinwood Gas-Works, Oldham,
Sept. 1, 1910.

Cost of Mill Lighting by Electricity, High-Pressure Gas, and Gas at Ordinary Pressure.

—	Electricity.				Compressed Gas.		Textile H.P. Lighting System.*	Gas at Ordinary Pressure.	
	1.	2.	3.	4.	5.	6.	—	7.	8.
Total initial cost of installation	£1460	£1650(*b*)	£1516	£2300	£800	£610	£300	£432	£450 (*b*)
Number of lights and candle power (nominal)	900—16 c.p.	1100—16 c.p.	987—16 c.p.	2000—16 c.p.	343—150 c.p.	206—150 c.p.	800—80 c.p.	400—60 c.p. Incand.	446—60 c.p. Incand.
	4—200 arcs	..	17—25 c.p.	..	40—15 c.p.	65—90 c.p. 19—60 c.p. 26—15 c.p.	..	50—15 Flat-flame	36—15 Flat-flame
Total nominal candle power	15,200	17,600	16,217	32,000	52,050	38,280	64,000	24,750	27,300
Horse power required for dynamo or gas compressor	90	90	100	160	1	1	0·25	..	..
Amount of coal per I.H.P. per hour	2 lbs.	6 lbs.	2 lbs.	2 lbs.	3 lbs.	3 lbs.	3 lbs.	..	..
Hours lighting per year	498	420	498(*b*)	552	440	440	460	..	..
Average renewals of lamp or mantles per year	216	200	288	500	360	432	800	1296	792
COSTS.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
4½ per cent. interest on capital	65 14 0	74 5 0	68 4 4	103 10 0	36 0 0	29 9 0	13 10 0	19 8 10	20 5 0
Depreciation—7½ per cent. on electric, 5 per cent. on gas	109 10 0	123 15 0	113 14 0	172 10 0	40 0 0	30 10 0	15 0 0	21 12 0	22 10 0
Coal at 12s. per ton	24 0 0	60 18 0	26 13 6	47 6 3	0 7 3	0 7 3	0 2 0	..	..
Renewal of lamps at 9d., or mantles at 4½d.	0 6 0(*a*) 8 2 0	7 10 0	10 16 0	18 15 0	6 15 0	8 2 0	15 0 0	24 6 0	14 17 0
Cost of gas, at 2s. 6d. per 1000 cubic feet (including gas used in electrically lit mills)	32 12 6	9 11 0	51 14 6	83 3 6	139 4 9	77 12 6 (*c*) 2 4 0	103 10 0	156 8 0	197 8 6
Total	240 4 6	275 19 0	271 2 4	425 4 9	222 7 0	148 4 9	147 2 0	221 14 10	255 0 6
Cost per candle power per year	d. 3·793	d. 3·763	d. 4·012	d. 3·189	d. 1·025	d. 0·929	d. 0·6	d. 2·150	d. 2·242

* I cannot take any responsibility for these figures, as I did not obtain them myself.—J. T.

(*a*) Carbons only for arc lamps. (*b*) These figures are estimated; actual figures not available. (*c*) Meter-rent charged in this case.

The following figures were supplied regarding mills Nos. 4 and 6, as representing the full costs to them of their lighting, and which are by them debited to their lighting account:—

Electricity, No. 4.

Previous total	£425 4 9
Proportion of running expenses, engines, boilers, &c.	69 6 8
,, ,, engine-room wages	18 0 0
Depreciation of buildings, £1000 at 2½ per cent.	25 0 0
Upkeep of electric plant	50 0 0
Total	£587 11 5
Total cost per candle power per year	4·838d.

Compressed Gas, No. 6.

Previous total	£222 7 0
22 weeks' wages, at 6s. per week	6 12 0
Total	£228 19 0
Total cost per candle power per year	1·055d.

Street Lighting.

SIR,—The prominence you have given to the victory of the London Gas Companies, in displacing the electric lighting of the finest thoroughfares in London, must give a great impetus to the use of gas for street lighting throughout the kingdom.

It would be interesting if you could follow the matter up by articles showing what is being done in the big provincial cities.

Is it not time for firms in the street-lamp business to wake up a bit? Being anxious to know what lanterns were being used for ordinary pressure inverted lighting, I looked through last week's "JOURNAL," but could get no satisfaction. I did find an adaptable fitting—a makeshift—and (would you believe it) a half-page illustrated advertisement of a flat-flame governor.

Would that the trade were as enterprising and up-to-date as the "JOURNAL."

Sept. 3, 1910. PROVINCIAL.

Falmouth Gas Company's Prosperous Year.—Presiding at the annual meeting of the Falmouth Gas Company last Thursday, Major J. Mead said that the last year had been the most successful in the Company's history. Though they made a reduction of 4d. per 1000 cubic feet in the price of gas, there was very little difference in their financial position; and in face of the introduction of electric light, they had 90 new consumers and an increase of 4 per cent. in the output of gas. A dividend of 6 per cent. was declared, in addition to the interim dividend of 5 per cent., making 11 per cent. for the year.

APPLICATIONS FOR LETTERS PATENT.

19,573.—DEMPSTER, R., AND SONS, LTD., and BROADHEAD, J. W., "Gas-purifiers." Aug. 22.

19,578.—HELPS, G., "Main-pipes." Aug. 22.

19,588.—NAGEL, H., "Gas-lighting apparatus." Aug. 22.

19,605.—VINCENT, W. J., "Universal joints." Aug. 22.

19,606.—STORER, J., and DE WITT, G. C., "Obtaining perfect incandescence of mantles with a greatly diminished consumption of gas." Aug. 22.

19,608.—SMITH, C. H., "Incandescent gas-lamps." Aug. 22.

19,617.—HUMPHREY, H. A., "Raising liquids." Aug. 22.

19,653.—HALL-BROWN, E., "Gas-producers." Aug. 23.

19,671.—GALVAO, M., "Incandescent lamps." Aug. 23.

19,697.—CUTLER, S., "Charging vertical retorts." Aug. 23.

19,750.—AKT.-GES. BROWN, BOVERI, ET CIE., "Gas-turbines." Aug. 24.

19,761.—GILBERT, H. R., "Solvent for carbon." Aug. 24.

19,814.—CHALLIS, J., and STEPHENS, K., "Globe-holders." Aug. 25.

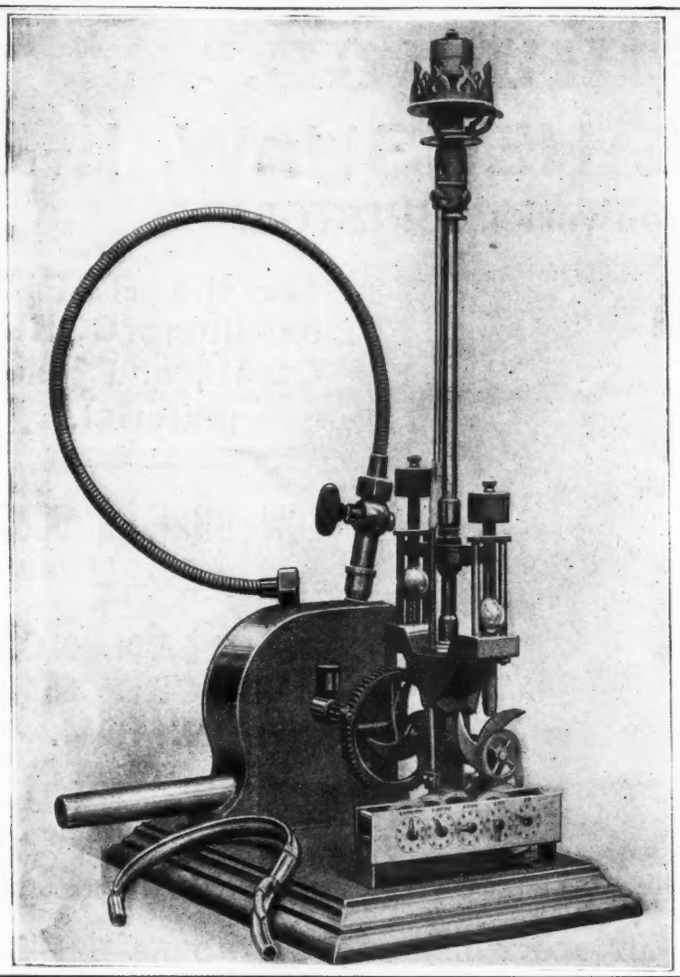
19,842.—KEITH, J. & G., "Gas-lamps." Aug. 25.

19,843.—BRITISH WELDING COMPANY, LTD., and CONSTANTINE, E. G., "Pipe-joints." Aug. 25.

19,902.—HOPKINSON, A., "Facing mouths of retorts." Aug. 26.

19,908.—WALLIS, W. H., "Gas-stoves." Aug. 26.

19,939.—ELY, B., and ROLLASON, A., "Treatment of coke." Aug. 26.



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For the RAPID handling of COKE, COAL, and other material.

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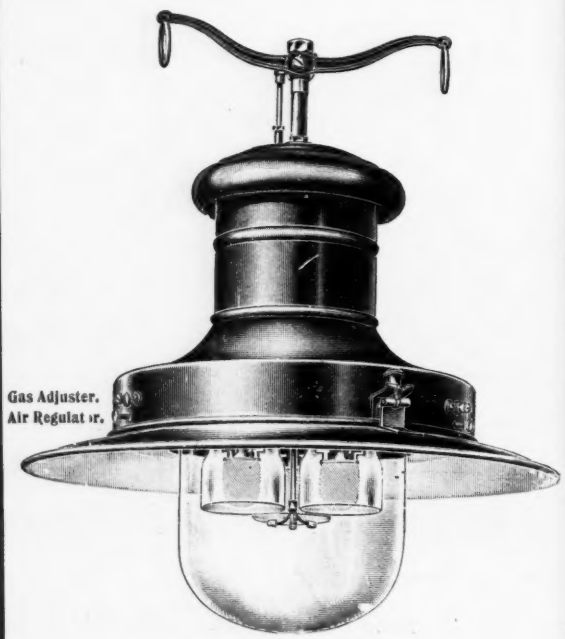

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Lighting Efficiency 125-c.p. per Burner.
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11,226. With Strong Steel Enamelled Casing, "GLASMI" Mantles, Inner Glasses, Clear Monopel or Jena Bowl, Gas Adjusters and Air Regulators, Outside Casing and Magnesia Nozzles.
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These Lamps can be supplied with Parabolic Reflectors if desired at a slight extra cost.

** *Subject to our usual Discount.* **

J. & W. B. SMITH,

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MISCELLANEOUS NEWS.

GAS SUPPLY OF PARIS.

Second Report of the Gas Company.

The Directors of the Company formed to carry on the gas supply of Paris in association with the Municipality, presented their second report at a meeting of shareholders recently held. It covered the twelve months ended the 31st of December last; and the following are its principal features.

The quantity of gas consumed in the above-named period was 429,241,411 cubic metres, or about 15,152½ million cubic feet; being an increase of 23,106,073 cubic metres, or rather more than 815½ million cubic feet, compared with the year 1908. This was 5·69 per cent. above the consumption that year, which was 4·23 per cent. higher than that in 1907. Of the gas sent out, 192,646,310 cubic metres, or close upon 6800½ million cubic feet, were used in the daytime; being 7·23 per cent. more than in 1908, which was an advance of 5·38 per cent. upon 1907. The revenue from sale of gas amounted to 79,917,411 frs. (£3,196,696), as compared with 75,660,511 frs. (£3,026,420) for the year 1908; being an increase of 4,256,900 frs. (£170,276), or at the rate of 5·63 per cent., compared with an improvement to the extent of 4·54 per cent. in 1908 over 1907. The number of consumers on the books at the close of 1909 was: Ordinary, 345,176; on the free-fittings system, 285,851—total, 631,027. The figures at the corresponding period of the previous year were: Ordinary, 331,275; on the free-fittings system, 276,874—total, 608,149. There was consequently an increase of 13,901, or 4·20 per cent., in the former class, of 8977, or 3·24 per cent., in the latter class, and of 22,878, or 3·76 per cent., in the total, compared with the year 1908.

For the public lighting of the city there were in use on Dec. 31 53,644 gas-burners, compared with 52,960 at the same period in 1908. They were divided as follows: Ordinary, 1244; incandescent, 52,400—being an increase of 698 of the latter and a decrease of 14 of the former. The number of rising pipes, for the supply of tenements, which at the end of 1908 was 53,355, increased in the course of last year to 54,193; the consumers taking their supply from them being 503,488, or 79·9 per cent. of the entire number, and 20,567 more than on Dec, 31, 1908. From the commencement of the Company's operations to the date just named, the mains were extended by 50,740 yards; bringing up the total length to 1,964,970 yards. In the twelve months just closed, 36,080 yards were added; making the total length at the end of the year 2,001,050 yards, or about 1140 miles.

As already mentioned, the revenue from the sale of gas last year amounted to 79,917,411 frs.; and beyond it residuals, meters, fittings, &c., produced 24,072,273 frs.—making together 103,989,684 frs. (£4,159,587). The expenses amounted to 80,076,538 frs. (£3,203,061); so that a sum of 23,913,146 frs. (£956,526) was available for the Municipality, compared with 22,571,067 frs. (£902,843) for 1908. In addition to the expenditure on the manufacture and distribution of gas, the sum of 80,076,538 frs. mentioned above includes interest and sinking-fund charges, taxes, the cost of new works, pensions and accidents, and the remuneration of the Company, amounting to 1,507,895 frs. This sum was brought up from various sources to 1,667,141 frs. (£66,686). Deducting 5 per cent. for the reserve, there was left a balance of 1,583,784 frs. (£63,352). Adding the sum of 182,894 frs. brought forward, there was produced a total of 1,766,678 frs. (£70,667). The Directors proposed a dividend of 5·25 per cent. for the year, which would absorb 1,575,000 frs. (£63,000), and leave 191,678 frs. (£7667) to be carried forward.

At the meeting of the Company last year, the Directors informed the shareholders that it would be necessary to carry out considerable extensions and improvements at the works, and that a series of proposals on the subject had been submitted to the Prefect of the Seine. [These have already been noticed in the "JOURNAL."] Particulars of the work done last year at the various stations, entailing an expenditure of 19,903,605 frs. (£796,144), are given in the report. The new works proposed will involve an outlay of 205,000,000 frs. (£8,200,000); and the Municipality of Paris have sanctioned the raising of a loan of this amount.

Before closing their report, the Directors bear testimony to the zeal and devotion displayed by the employees in all departments of the Company. After the disastrous floods early in the present year, the Prefect of the Seine conveyed to the Directors the congratulations of the Gas Committee of the Municipality, with which he associated himself, on the admirable way in which the *personnel* had discharged their duties.

HAMBURG GAS UNDERTAKING.

Report for the Year 1909.

The "Journal für Gasbeleuchtung" for Aug. 27 gave a summary of the report of the Lighting Committee of the Hamburg Corporation on the working of the gas and electricity undertakings of the city during the year 1909. We take from it the following particulars.

The total consumption of gas amounted to 97,305,200 cubic metres (about 3,436,392,000 cubic feet), which is an increase of 5·65 per cent. on that for the preceding year. The curtailment of public lighting rendered necessary by the disaster to the gasholders at the Grasbrook works on the 7th of December, caused the increase in consumption to be somewhat less than had been anticipated. Of the total output of gas, 30·2 per cent. was provided by the Grasbrook works, 39·9 per cent. by the Barmbeck works, and 29·9 per cent. by the Billwärder works. The Grasbrook accident threw a portion of the normal work of that station on to the Barmbeck works, where the carburetted water-gas plant which is intended to be worked in the daytime only (and merely to take up fluctuations in consumption) had to be worked day and night at full load for some time after the accident.

Since December, 1905, gas has been sold in Hamburg at the uniform price of 14 pf. per cubic metre (say, 4s. per 1000 cubic feet); and it has ceased to be possible, as formerly, to ascertain the proportions consumed for different purposes. There probably, however (the report states), was only a slight increase in the sale of gas for lighting, owing to the wide adoption of the more economical inverted burner quite as much as to the competition of electricity. The consumption of gas for heating (and especially cooking) purposes has, however, advanced very considerably. The unaccounted-for gas amounted to 2·62 per cent. The burning out of the gasholders at the Grasbrook works was responsible for a loss of about 4,600,000 cubic feet of gas. Coal was bought at lower prices than in 1908, and wholly from England, as the Westphalian supplies proved too dear. Coke fetched rather better prices; but ammonia, coal tar, cyanogen sludge, and spent oxide were all lower, and buyers were scarce even at the reduced prices. Oil gas tar sold, however, for better figures than previously.

More machinery was introduced in the retort-houses, with a resultant saving in the wages account. Some of the horizontal retorts were lengthened. The vertical retorts at Grasbrook worked well, and a high make of gas was obtained from the inclined retorts both there and at Billwärder. The large carbonizing chambers, after reconstruction of their superstructure, worked very satisfactorily. A further series of fourteen beds of these chambers has been under construction at the Grasbrook works, and half were finished in the year. The reconstruction of the works was continued, but delays occurred. The work of clearing the old gasholder of 50,000 cubic metres capacity, which was burnt out with the large new one, preparatory to its reconstruction, was put in hand at once.

The number of gas-meters in use at the close of the year was 128,215, which is an increase of 8·6 per cent. The prepayment meter installations were increased in number from 336 to 1429. With each five-light prepayment meter were supplied a two-burner cooker, one or two pendants, and two or one wall brackets—each with incandescent burners. The gas undertaking, however, requires the requisite service pipes to be provided, or at least to call for very small alteration. The price charged for prepayment meter supplies is 16 pf. per cubic metre (4s. 6d. per 1000 cubic feet) as compared with 14 pf. for ordinary supplies (*vide supra*). The length of distributing mains was extended by 4·4 per cent.; and in streets where the subsoil was bad a considerable length of Mannesmann steel mains, from 2 to 10 inches in diameter, were laid. For public lighting, the number of lanterns with four inverted gas-burners was increased, and they will continue to be introduced in streets where there is much traffic. The number of gas-lamps for public and private street lighting was 26,333, of which about 580 (mostly private property) still have flat-flame burners. A large number of the lamps have more than one incandescent burner. There are also used for public lighting 529 arc lamps, 463 electric glow lamps, and 62 Nernst lamps. The gas undertaking passes all new gas services before they are allowed to be used, and all the larger installations are tested by its officers for soundness.

The report gives no fresh information regarding the cause of the collapse of the tank of the new gasholder of 7,100,000 cubic feet capacity, or as to its reconstruction.

ZÜRICH GAS UNDERTAKING.

Report and Accounts for the Year 1909.

We have received through the courtesy of Herr A. Weiss, the Engineer and Manager, a copy of the report and accounts of the gas undertaking of the Corporation of Zürich for the twelve months ended Nov. 30, 1909. As usual, the report contains an immense mass of detailed information and numerous diagrams relating to the working for the year, from which only the more important particulars of general interest have been abstracted in the following *résumé* of its contents.

The success which has attended the installation of Dessau vertical retorts in the No. II. retort-house of the works at Schlieren has led to the decision to equip the No. I. house with similar plant; but the execution of this project is being postponed because the productive capacity of the existing plant is ample for all present requirements. Owing to the lack of suitable workmen's dwellings in the neighbourhood of the Schlieren works, the Corporation have voted a sum for the erection of eight houses adjoining the works; and they will be built in the ensuing year. The distributing system has been extended in the course of the twelve months by the addition of about 8521 yards of mains. The ten settings of vertical retorts were in use continuously during the year; and the fluctuations in gas consumption were taken up entirely by the inclined retorts. With eight-hour shifts, the average number of men employed on the vertical retorts was 8·3 per diem. In this computation are included the stokers who are engaged charging and discharging the retorts, and in clinkering and charging the producers, and the men employed in clearing ascension-pipes and hydraulic-mains, cleaning and lubricating retort-lids, and keeping the stages, settings, and conveying troughs clean.

The total amount of coal carbonized in the year was 89,916 metric tons (= about 88,495 tons), and of cannel 525½ metric tons; and the total make of gas was 30,709,700 cubic metres (= about 1,084,513,100 cubic feet). The average make of gas per ton of material carbonized was therefore 12,186 cubic feet, which is a slight increase on the make per ton in 1908. Of the total coal used, 41,000 tons were carbonized in the vertical retorts, with an average make of 13,299 cubic feet per ton, as compared with a make of 11,264 cubic feet per ton for the coal (including the 525½ metric tons of cannel) carbonized in the inclined retorts. The calorific power of the mixed gas was tested daily, and averaged for the year 517 B.Th.U. net per cubic foot at 60° Fahr. 30 inches and saturated. A Junkers registering calorimeter was used to control the working, and was found satisfactory, provided

its readings were constantly checked. A Lux gas-balance, which was also used, gave less satisfactory results for control purposes.

The cost of coal (including cannel) delivered into the retort-house was 27s. 8d. per ton, which is a trifle lower than in 1908. The total make of gas (*vide supra*) shows an increase of 6·47 per cent. on that for the preceding year; but since the unaccounted-for gas was slightly less (4·22 per cent., against 4·64 per cent. of the make) than in 1908, the increase in the amount of gas sold to private consumers was 6·66 per cent. This compares with an increase of 10·58 per cent. in 1908. The gas consumed for lighting purposes has fallen from 17·16 per cent. of the make in 1908 to 15·99 per cent. in the past year. The gas sold expressly for heating and cooking purposes is now 59·75 per cent. of the make, against 57·77 per cent. in 1908. Public lighting accounts for 8·32 per cent. of the gas made. In connection with the Gordon-Bennett Balloon Competition on Oct. 1 to 4, about 3,895,300 cubic feet of gas were supplied gratis from the works for filling the balloons. The average consumption of gas per head of the population within the city boundary amounted to 4955 cubic feet, as compared with 4686 cubic feet in 1908, exclusive of gas used for public lighting and unaccounted-for gas. The coke consumed in the retort-furnaces amounted to 14 lbs. per 100 lbs. of coal carbonized with the inclined retort-settings, and to 15 lbs. with the vertical retorts, in which a proportion of water gas was made by the admission of steam. The following tabular statement shows the percentages by weight of the bye-products obtained per 100 parts of coal carbonized, during the last four years. Prior to 1908, the coal was carbonized entirely in inclined retorts.

Year.	Coke.	Real Ammonia.	Tar.	Thick Tar or Pitch.	Producer Clinker.	Retort Scurf.	Prussian Blue.
1909	72·95	0·2389	6·15	0·40	3·62	0·037	0·056
1908	72·95	0·2279	6·04	0·31	3·41	0·071	0·067
1907	70·11	0·2063	6·26	0·24	4·15	0·060	0·115
1906	73·37	0·1975	6·34	0·37	3·68	0·093	0·083

The prices obtained for liquor, cyanogen sludge, and spent purifying material (chiefly Giulini material—an artificial alkalized oxide of iron) were lower than during the previous year. The cyanogen sludge produced contained 8·1 per cent. of prussian blue and 5·7 per cent. of ammonia. The cyanogen extracted was equivalent to 0·805 oz. of cyanogen per 1000 cubic feet of gas treated. The naphthalene extracted in the oil-washer was equal to 5·6 oz. per 1000 cubic feet of gas. The gas distributed contained on the average, per 100 cubic feet, 18·8 grains of sulphur, 5·7 grains of cyanogen, and 0·025 grain of ammonia.

The experimental gas-making plant, comprising a setting of two horizontal retorts, was brought into use last year; and the results of investigations made with it have already been published.* Researches were also made on the carbonizing conditions prevailing in vertical retorts, from which it appeared that the gas evolved probably ascends between the coke and the walls of the retort, and not through the core of coal. More gas appears to be produced (the report says) in the vertical retort, because of the more thorough decomposition of the constituents of the gas; while rather more coke, but certainly not more tar and ammonia, results. The thinness of the tar is probably due to its particles having been subjected to a filtration process in passing through the block of coke. An investigation was made on behalf of a private party as to the effect of adding limestone to the coke used as fuel in gas-producers and working the latter with dry air. The intention was to obtain caustic lime, and an addition of carbonic oxide to the producer gas. But it was found that the temperature of the retort-setting fell off rapidly owing to the depth of the bed of coke being insufficient, when the limestone was present, to furnish enough gas and reduce the carbonic acid to carbonic oxide. The lime also was badly burnt. It is possible that the process might answer in a specially constructed producer and setting, with a deep bed of fuel; for though the limestone would not afford any direct gain in heat, it would serve, like the steam admitted to producers, to secure a more favourable distribution of energy in the furnace and setting. The practical importance, if any, of the process, can, however, only be determined by special investigations; and local conditions in respect of the supply of limestone and the disposal of lime would play an important part.

The number of public lamps in use was 6460, containing 8031 burners. The number of automatic lighting and extinguishing appliances fitted to them was increased by 87—making the total 1550. Only 51 lamps had flat-flame burners. The mantle renewals during the year averaged 7·33 per burner, and the chimney renewals 3·27. The experiment begun the previous year of supplying milk to the men on the works at a price of 10 centimes per litre (= about 1·1d. per quart) was continued; but there was a falling off in the quantity sold. A loss of about £45 was incurred in the sale of milk; and coffee, which was supplied gratis, cost about £35. The accounts show a net profit on the year's working of the undertaking of 1,279,501 frs. (about £51,180).

* See "JOURNAL," Vol. CVIII., p. 184.

Abertillery Water Board.—Representatives of the Risca, Abercarn, Mynyddislwyn, and Abertillery District Councils met at Newport on Wednesday last to appoint officers for the new Abertillery District Water Board, which comes into operation on the 12th prox. Mr. George Jones (Abertillery) was appointed Chairman. The question of selecting Engineers was discussed, but no decision was come to. It was decided to hold monthly meetings at Newport. The Board's proposals involve an expenditure of £250,000.

Berwick Water Supply Scheme.—The Local Government Board having issued an ultimatum giving the Berwick Council one month to submit satisfactory proposals for a water supply for the borough; and the month expiring on the 3rd inst., a special meeting of the Council was held last Wednesday. It was agreed by 11 votes to 10 to send to the Local Government Board a sectional scheme prepared for supplying Tweedmouth and Spittal alone, costing £14,200. The Treasurer estimated that this would mean a special rate of 3s. 4d. in the pound. The scheme was severely criticized by the minority, who favour a joint scheme, including Berwick, and costing £20,000.

AUSTRALIAN GASLIGHT COMPANY.

The Annual General Meeting of this Company was held at the Offices, in Sydney, on the 28th of July—Mr. G. J. COHEN, the Chairman of the Company, presiding.

The SECRETARY (Mr. R. J. Lukey) having read the advertisement convening the meeting, the report of the Directors was taken as read. They stated therein that the profits for the half year ended the 30th of June, after making provision for bad and doubtful debts, deducting interest on borrowed money, repairs and renewals, depreciation of plant, working expenses, and all other charges (including the transfer from reserves towards meeting the loss resulting from the coal strike) amounted, with the balance brought forward, to £69,745; and they recommended the payment of a dividend for the six months of 9s. per share on the old shares, and in proportion on the new shares, free of income-tax. This would absorb £62,450, and leave a balance of £7295 to be carried forward. The report of the Engineer (Mr. T. J. Bush, M.Inst.C.E.) on the Company's plant was stated to be most satisfactory. The coal strike entailed a loss to the Company of upwards of £70,000, notwithstanding that they had six weeks' supply of coal to work upon. They nevertheless bore the loss without increasing the price of gas. Had this been raised, it would have necessitated a charge of 7s. per 1000 cubic feet being made to the public while the strike lasted, to recover the amount. The Board had to take £40,000 from the reserve fund, in addition to a provision made last half year, in order to pay the usual dividend.

The CHAIRMAN, in moving the adoption of the report, said that when he addressed the shareholders on the last occasion, they were in the throes of a coal strike, more disastrous than any previously experienced in the State. The severity of the strike had not to any great extent been felt by the Company during the half year ending December last; but there were signs—owing to a scarcity of coal and the enormously high price ruling for it—that the Company would be called upon to meet heavy losses. The Board, however, hardly anticipated that these would be as great as eventually proved to be the case. Of course, at such times there were always to be found those who could tell what the Company should have done under such circumstances; but it was easy to be wise after the event. He very much questioned whether any gas company of similar magnitude, situate so near coal-fields, kept such a large stock of coal as they did—six weeks' stock, which completely filled the stores, equal to nearly 25,000 tons, when the strike commenced. It was evident that strikes would occur, he said, no matter what laws were enacted; but with the Arbitration Act and Wages Boards in operation, strikes of such duration as the last ought not to be possible. However, the Board had the satisfaction of knowing that the gas supply did not fail, neither was the price of gas raised. The cost to the Company (over £70,000) was severe; and it was felt by the Board that as the consumers had been so generously treated, the shareholders should not suffer by the loss of dividend in consequence, although to maintain the usual rate it had been found necessary to deplete the reserve fund to the extent of £40,000. Notwithstanding this, a certain amount was set aside last half year, which the Directors hoped would be sufficient to meet the additional expenditure consequent upon the strike.

A great deal had appeared in the local Press of late respecting the price charged to consumers for gas, and the dividends paid to the Company's shareholders. He thought the time chosen for making these charges was inopportune, considering the loss sustained by the Company in their successful endeavours to continue the supply of gas at such a critical period without raising the price, as many companies would have done under similar circumstances. He would say, however, that the Directors had always, when possible, reduced the price of gas—in fact, the price would be lower now but for the continued increase of late years in customs duties, wages of workmen, and price of coal. Some writers had erroneously supposed that the use of carburetted water gas had tended to cheapen the cost of manufacture; but this was not so, for it cost more to make than ordinary gas. The plant, however, was very convenient in regulating the sale of coke. The quantity of oil used by the Company per annum was about 1,250,000 gallons. This, of course, took the place of shale, of which they formerly used a large quantity.

With reference to the dividend, notwithstanding that the present rate, 15 per cent., had not been altered for many years, the price of gas to private consumers had been reduced from 8s. 6d. to 4s. per 1000 cubic feet, and the public lights from £8 10s. to £4 per lamp per annum, although the agreements in force at the time contained provision for the payment of a higher rate than was charged. He was at a loss to understand the arguments of some people who did not object to a 10 per cent. dividend, yet were adverse to the Company paying 15 per cent. on £6 paid-up shares issued at a premium of £6, or £12 per share in all—thus practically only returning 7½ per cent.—which had been done for many years. But to the present investor, the rate was still further reduced to about 5 per cent., if based on the market price of the shares to-day. The whole of the Company's capital had practically now been subscribed. Before long, power would have to be sought to increase it; and the Directors would be able to approach the Government, when the time arrived, with every confidence, as the result of the satisfactory way they had carried out their obligations to their customers, who really were the general public.

The increase in the consumption of gas for the half year was nearly 8 per cent. The existing mains in several districts were being taxed to the utmost. To cope with the anticipated output for next winter, it had been found necessary to make arrangements for increasing the plant at the manufacturing stations during the present summer. The Directors were sorry to make a charge for the use of subsidiary meters, but were compelled to do so in the interests of the Company. For instance, in suites of offices containing as many as eighty meters, it was found that the majority of them were not in use, and many that were only used a few pence worth of gas per annum. In this way, more than 3000 meters were out; and it was considered that the time had arrived when they should either be returned to the works, or a small rental charge made for their use, if retained. This regulation did not,

of course, apply to "master" meters—these being supplied as heretofore, free of charge, as all ordinary meters were. "Consumers deposits" was another item that seemed to exercise the minds of some people; but it should be known that this was not a fixture. Amounts were paid in, and refunded daily; so that the balance of receipts and refunds during the year was oftentimes exceedingly small. With few exceptions, the time-limit was two years; and in all cases, interest at the rate of 4 per cent. per annum was allowed.

Referring to the Company's operations during the past half year, he said it was pleasing to note that, notwithstanding the adoption by the city and some of the suburbs of electricity for public lighting, the number of gas-lamps was still very satisfactory—being 11,083, or 57 more than six months ago. The sales of cookers had increased 817—making the total number sold by the Company to date 19,916. It was impossible to say how many had been disposed of by private firms; but the number must be very considerable. The day consumption of gas kept about the same as usual—viz., 46 per cent. of the total deliveries. During the half year the Company laid 29 miles of main and service pipes. The total quantity now laid was 2450 miles. The increase in the number of consumers was 2406—making a total in the books of 92,644. The increase in the number of prepayment meter consumers had not been as large as usual, owing to the inability of the Company to at present extend the system to many of the suburbs; but they hoped shortly to do so.

In concluding his remarks, he acknowledged the special services of the Secretary (Mr. R. J. Lukey), the Engineer (Mr. T. J. Bush), and the other members of the staff during the trying period of the strike, which the Directors fully appreciated.

The motion for the adoption of the report, and the payment of the usual dividend, was seconded by the Deputy-Chairman (Hon. Henry Moses, M.L.C.), and carried unanimously.

There being no opposition, the Chairman declared the retiring Directors and Auditors re-elected.

A hearty and enthusiastic vote of thanks was then passed to the Directors and officers for their services during the past half year, special mention being again made of the strenuous times experienced by the Company in connection with the late disastrous coal strike.

GAS v. ELECTRICITY AT HASTINGS.

The report for the six months to June 30, which was presented at the half-yearly meeting of the Hastings and St. Leonards Gas Company last Thursday, stated that the Bill to legalize the use of the No. 2 "Metropolitan" argand burner for official testing, mentioned in the last report, duly passed all stages in the House of Lords, though opposed by some of the local authorities. It was further opposed in the House of Commons on second reading, and referred to a Select Committee, who, after eleven days' hearing, unanimously declared the preamble proved. The Bill now awaits a third reading in that House. The accounts duly audited showed a profit balance of £13,063. After writing off £1000 on the old works and plant, the Directors recommended that dividends for the half year be declared at the statutory rates per cent. per annum, less income-tax—namely, £6 10s. on the 5 per cent. converted stock, £5 on the 3½ per cent. converted stock, and £6 1s. on the 5 per cent. additional stock—and that the balance be carried to the next account.

Presiding at the meeting, Dr. G. G. Gray, J.P., the Chairman, drawing attention to the statement in the report that the Bill promoted to legalize the No. 2 "Metropolitan" burner had passed the second reading of the House of Commons, remarked on the opposition that was offered by local authorities, Hastings included. At the end, the opposition, he said, had been reduced to two towns—Hastings and Liverpool. The reason for Liverpool's opposition could be understood. But why had Hastings continued to oppose until the bitter end? In what respect did Hastings differ from all the other forty authorities affected by the Bill? He had come to the conclusion that the majority had decided to oppose either through ignorance or through enmity. They either did it because they did not understand what they were doing, or in order to damage the Gas Company in the interests of the electricity undertaking. The old burner was defective, unscientific, extravagant, and out of date. The new burner was scientific and an improvement. It would reduce the consumption of coal, and thus make for economy, of which saving three-quarters would go to the consumers and one-quarter to the stockholders, or, to put it into figures, the consumers would save £1920, and the stockholders £437. So that, while there would be a benefit to the stockholders sufficient to induce the Gas Company to do all they could to reduce the price of gas, a far higher proportion of the benefit derived went into the pockets of the consumers. In attempting to deprive consumers of this benefit, and in putting the ratepayers to the expense of opposition, it was quite evident that the Corporation had not acted in the interests of the consumers. The ratepayers when they came to understand the expense they had been put to—if they ever did understand it; for it was generally given to them in driblets at different Council meetings—would, he thought, be of the same opinion, that it had not been in their interests. The question naturally arose: Would the Corporation have gone to all this trouble, and would they have incurred all this expenditure, if they had not—most unfortunately for them, and most unfortunately for the ratepayers—been the owners of the electricity undertaking? The fact that other local authorities not possessing electricity undertakings did not oppose, or, if they did, dropped the opposition when they understood what the Bill really meant, suggested that the Hastings Corporation would not have done otherwise. What other inference was there than that they had opposed in order to prevent the price of gas being reduced, because they feared that such reduction would be detrimental to electric light as handicapping it still more in comparison with gas? In other words, because the Corporation could not produce electricity at a reasonable and paying price, therefore, so far as the Corporation could prevent it, the price of gas would not be reduced. Thus an acting majority in the Council showed its greater wisdom or folly than other towns—not only the forty in the Bills, but the seventy odd companies, and the seventeen local authorities who already possessed the powers sought. Was there any consumer or ratepayer foolish enough to think that, out of all these towns, the acting majority of the Hastings Council were the only ones that possessed wisdom, and that such wisdom would die with them? It might be a good thing for the town if such wisdom and such actions did. They met after a satisfactory half-year's working. The profit was an increase of £251 on the corresponding period last year. This was not due to increased revenue, but to more economical working. There had actually been a decrease in revenue of £952; but expenditure had decreased by £1202—thus accounting for the £251 increase in profits. Owing to the bad state of the coke trade, there had been a decrease in the receipts for the sale of coke of £395. There had been £1326 less spent on coals.

The report was adopted, and the dividends recommended were declared.

BARNET DISTRICT GAS AND WATER COMPANY.

Improved Working Results.—Recent Litigation.

The Half-Yearly Meeting of this Company was held yesterday week at the Holborn Restaurant—Mr. ALFRED H. BAYNES in the chair.

The SECRETARY (Mr. Ernest W. Drew, F.C.A.) read the notice convening the meeting; and the Directors' report and the accounts were taken as read.

The CHAIRMAN, in moving their adoption, said he thought the shareholders would agree with him in regarding the outcome of the past half-year's business of the undertaking—notwithstanding many difficulties and anxieties—as exhibiting very gratifying progress and prosperity, reflecting great credit on their Engineer (Mr. F. J. Bancroft) and the efficient staff working with him. He would deal first with the gas department. In the gas capital account it would be noted that no expenditure appeared for works; the outlay for the half year (£540) being for new mains, services, and meters. In the revenue account, compared with the corresponding period of last year, they had a very pleasing increase—namely, on private lighting £686, on public lighting £40, on rental of meters £48, and on rental of stoves £51. This made a total gain of £825. The number of consumers had been increased by 262; while 227 additional cookers had been sent out, and 73 boiling-rings. He found on inquiry that during the last two years the Company had been able—by persistent effort—to lay 949 new gas-services. This, he considered, was a satisfactory increase, of which they were now beginning to feel the result; and he looked forward to even a further increase from these new consumers. They were now getting more and more the confidence of the consumers; and the showroom attendants and fitters were kept well at work. During the past half year the Company had fixed nearly 1000 gas appliances for their consumers; the principal result being satisfaction to the customer, who obtained first-class and economical goods giving the best effect for the gas consumed. If the gas in a house furnished a poor light, it was so easy to at once blame the gas company; and some even seemed to think the company took a delight in worrying their best friends—the consumers. He was pleased to say they could fairly meet such cases, in two ways especially: (1) The Local Authority had, as the shareholders were aware, appointed an independent Gas Examiner; and this impartial gentleman had certified the gas to have a considerable margin of illumination in excess of the standard prescribed by Parliament for the Company. (2) The fitters, by cleaning the consumers' appliances or by fixing new fittings, conclusively showed to the customers that they had only to make use of the men and appliances the Company had provided to get their illumination and heating effects at the highest efficiency, and at the same time economically. The gas made during the past six months, as compared with the same half of 1909, exhibited an increase of 2,561,000 cubic feet; while the quantity sold was 3,861,000 cubic feet more. The make of gas per ton of coal had been 12,558 cubic feet, against 11,657 cubic feet the previous year; the sale per ton, 11,677 cubic feet, instead of 10,610 cubic feet. The aggregate receipts from residuals (coke, breeze, tar, and sulphate) for the six months were £3425, as compared with £3437 last year. This amounted to 66 per cent. of the cost of the coal. Turning to the expenditure side of the account, he would point out that during the six months coal cost £5176, or £545 less than in the corresponding period. This saving had been effected first, in consequence of the favourable contract the Company made; and, secondly, as a result of improved working, for it must be noted that the gas made in the six months had been 77,493,000 cubic feet, against 74,932,000 cubic feet last year (an increase of 2,561,000 cubic feet), and the quantity carbonized had been reduced from 6428 tons to 6171 tons, or a saving of 257 tons, notwithstanding the increase in the total make of gas. This, the proprietors would agree with him, was a most satisfactory result, and showed excellent management, and the wisdom of the thorough overhaul and reconstruction of the works that had been carried out. The first result of this greater efficiency of the gas undertaking had been given to the consumers, in the shape of 2d. per 1000 cubic feet reduction in price; and this, he hoped, would induce them to increase their use of gas in the many ways in which it was now adapted to minimize work and increase comfort. Purification had cost £53 more; but he trusted they would be able to economize in this direction, owing to the improved plant now erected. Wages at the works also showed a slight increase of £36; and repairs of works were £463 more. Then the repairs of mains had increased by £467, which had been chiefly expended in taking up old mains and in renewing others. As the result of this work, they saw a decrease in the unaccounted-for gas, which was now 6·01 per cent., compared with 7·49 per cent. last year. The only other item to which he need draw attention was rates and taxes, which now amounted to £1000 per half year over the gas section, or equal to 3d. per 1000 cubic feet sold. The net result of the six months' working showed a profit of £3659, against £3368, or an increase of £291.

Referring now to the water department, he would point out that the receipts from water-rates showed an increase of £955. Empties were

slightly less; and the net result was an increase of £958 for the half year. On the expenditure side of the account, repairs of works had cost £102 less, and repairs to mains £595 less; while pumping charges and engineer's and other salaries grouped together were this year £3305, against £3251 in the corresponding half of 1909. The only item under "Management" to which he need specially refer was that of "Law." Under this head, in the past six months they had spent £890, as compared with £117 last year. This had been in connection with the action brought by the Attorney-General against the Company to prevent the sinking of a new well at Tyttenhanger. It would be remembered that in their last report the Directors were able to state that the judgment of the Court of Appeal had been given in favour of the Company. The case was, however, taken to the House of Lords, and, without calling upon the Company to present their arguments, the appeal was dismissed, and judgment delivered on every point in favour of the Company, with costs. In the words of his valued colleague, Mr. A. F. Phillips, when addressing the shareholders twelve months ago: "The Barnet Board from the first had the clear conviction that under their Act of Parliament they had the right to take water at Tyttenhanger; and as, according to an old proverb, 'he who exercises a right does no one an injustice,' the Board felt that they ought, by every lawful means in their power, to secure the rights they believed Parliament intended they should possess. To this there was no alternative—their rights must be maintained and firmly established." In this connection, it was only just to state that the Engineer gave unremitting attention to this anxious business, and rendered most effective service; and the Secretary, also, was in constant attendance during the appeal, and gave valuable help. In addition to this heavy outlay, a Private Bill was introduced into the House of Lords, entitled the Water Supplies Protection Bill, which proposed, on the one hand, to considerably curtail the powers of water companies, and, on the other, to increase their obligations. In particular, it would have inflicted great hardship on the Barnet Company. The Bill was sent to a Hybrid Committee to take evidence; and the Board presented a statement showing how the measure would injure the Company, and the Engineer gave evidence thereon. Other companies, and also corporations, opposed the Bill; and after a protracted hearing, the Committee's proceedings were—briefly summarized—against the measure further proceeding. Directly the Court of Appeal had given judgment in the Company's favour, the work at Tyttenhanger was resumed; and it was being proceeded with as fast as possible. The main wa salso being laid to convey the water from the well to the reservoir at Arkley; and the whole of the works would be vigorously pushed forward so that at an early date the water might be available to meet the growing necessities of the Company's large and important water area. Under the head of water capital, there was an expenditure during the half year of £9192, nearly the whole of which had been in connection with the new main from Tyttenhanger already referred to. Some £70 had been spent on new meters, &c., making the total capital expenditure for water for the past six months £9262. The quantity pumped into the district was 301,478,000 gallons.

The total profit for the past half year was £14,088—from gas, £3659; from water, £10,301; and from fittings, £127. From this had to be deducted interest and income-tax, £2252, leaving a net profit of £11,836, which was an increase of £1196 when compared with 1909. The payment of the dividends recommended in the report would absorb £9855; and £1000 was carried to the contingency fund. This left a surplus of £981, which, added to the sum of £18,243 brought forward from last year, left a balance of £19,224 to be carried forward to the new account.

Mr. Alfred Lass seconded the motion.

Mr. C. P. Crookenden, remarking that the decided improvement in the working of the gas department reflected very great credit on the staff, inquired what was the statutory illuminating power. While admitting that the reduction in price which the Board had seen their way to make was satisfactory, he asked whether any discount was allowed on gas used for cooking and heating. In the case of another company in which he was interested this plan had been adopted, and there had been a marvellous increase in consumption. He believed that a rebate of 6d. per 1000 cubic feet was allowed off gas employed for cooking and heating, and that the result had been to send up the consumption some 50 per cent. With the price of gas as at present, unless some special inducement was offered to consumers, he did not think that at Barnet they would get the increase they should in this direction. Referring to the undivided balance carried forward, he said this was rather large, and a good many shareholders, seeing the amount, asked why they could not have a little higher dividend. He was satisfied that the policy of the Board was a good one; but if they carried less forward, and put more to the contingency fund account, the objection he had pointed out might be obviated.

The Chairman replied that the prescribed illuminating power was 14 candles. With regard to the balance, the Company were incurring heavy expenditure, and it was therefore undesirable that the amount should be reduced. There would be big claims upon this balance almost immediately, which he hoped would place the business in a very fine position.

The resolution was then carried unanimously.

On the proposition of the Chairman, seconded by Mr. Frederick Lennard, dividends were declared, less income-tax, for the half year, at the rates per annum of 7½ per cent. on the "A" and "C" stocks, 6½ per cent. on the "B" stock, and 5¼ per cent. on the "D" capital gas and water stocks.

Mr. A. F. Phillips, in proposing a vote of thanks to the staff, remarked that he knew it was the custom of shareholders to pass such votes as an ordinary routine matter, if the accounts were reasonably satisfactory. The proprietors would, however, have gathered from the statements of the Chairman that a special vote of thanks was due to their officers this half year. They had passed through a most anxious time, and had settled questions which had really been vital to the existence of the Company. Mr. Drew had had an immense amount of information to prepare in connection with the litigation; and to Mr. Bancroft their warmest thanks were due for the very able manner in which he had got together the statistics for the appeal to the House of Lords, and for the valuable evidence which he had given in connection with the Water Supplies Protection Bill. He felt sure that Mr. Bancroft's evidence on this Bill, coupled with that of their friend Mr. W. B. Bryan, had very materially affected the decision at which the Committee arrived. All this time, too, their Engineer had been deeply occupied with the works at Tyttenhanger. There had been the well, which was now just on the point of completion, and there had also been the preparation of the specifications and plans for the pumping plant, the tenders of which had been accepted that morning. The Directors hoped that when they met the shareholders this time next year, they would be able to report that water was being delivered from Tyttenhanger. For all these special services which had been so ably rendered by the staff, he asked the shareholdors to accord them a hearty vote of thanks.

Mr. W. B. Bryan said no one knew better than he himself did the difficulties which they would all have been placed under had the Water Supplies Protection Bill been passed. It should have been "Private Supplies Protection Bill," not public water supplies, because undoubtedly if the Bill had passed it would have hit all the water authorities simply for the protection of private supplies. The staff must have had an immense amount of trouble, labour, and anxiety; and he was pleased to second the vote.

The motion having been heartily seconded, Mr. Drew, Mr. Bancroft, and Mr. Wright (the Rental Clerk) returned thanks. Mr. Bancroft remarked that the last two years had been a very anxious time, but particularly so the past six months. He had, however, to acknowledge the great assistance he had received from the Board, and particularly from Mr. Phillips, who had devoted a great deal of time to the business. The well-sinking at Tyttenhanger had gone on most satisfactorily. Messrs. Docwra and Son had laid 8 miles of 20-inch water-main in nine weeks—a performance which reflected great credit on them and on the makers of the pipes. He trusted next year to be able to report that they were pumping water from Tyttenhanger.

The proceedings closed with a vote of thanks to the Chairman and Directors, on the proposition of Mr. Samuel Spencer, seconded by Mr. F. R. Smith.

SHREWSBURY GAS COMPANY.

At the Annual Meeting of this Company on Thursday, the Directors reported that the profits on the year's working to the 30th of June amounted to £8300; and they recommended a final dividend of 3½ per cent., making, with the interim dividend, 5½ per cent. for the year. The Chairman (Mr. T. F. Poole), in moving the adoption of the report, referred to the loss the Company had sustained by the death of the Deputy-Chairman (Mr. Henry Wade), who had, he mentioned, served the Company for 35 years—20 as Auditor and 15 as Director—and had been most assiduous in his attention to his duties. With regard to the Company's progress, the Directors had great pleasure in being able to submit another favourable report, the more so as the past year had been one of some difficulty. First, he must point out that the Company's business was still flourishing, and they had that day more customers for both light and heat than at the corresponding time last year, though they had had a reduced consumption of nearly 1½ per cent. This was due entirely to the mild season, and especially to the months of January, February, and March, during which they had very little of the usual frost; and in a residential town like Shrewsbury, the consumption of gas was very sensitive to differences of weather. The other features he wished to mention were a good reduction in the cost of coal, due mainly to better results obtained from the mixture of coal used during the year, and the fact that they had renewed all their retorts and furnaces in the new works. On the other hand, there was the continued increase of taxation, and also they had had to contend with a poor market for residual products. For the coming year, they were having to pay an increased price for coal; and in the apprehension of more friction resulting from the Mines (Eight Hours) Act, they thought it advisable to have as large a stock as they conveniently could. They hoped, however, for some improvement in the residuals market, and by careful management to obtain some reduction in working expenses, which they trusted would enable them to present to the shareholders next year a report as satisfactory as the one now before them. The works and plant had been kept in a thorough state of repair and efficiency. The Chairman concluded by making a few remarks on the Standard Burner Bills. The report was adopted, and the dividend recommended declared. Thanks having been accorded to the Chairman and Directors, Mr. Poole responded, and proposed a similar compliment to Mr. William Belton (the Engineer, Secretary, and Manager) and the staff. Acknowledgment of the vote by Mr. Belton brought the meeting to a close.

Improved Plant and Increased Gas Consumption at Truro.—At the meeting of the Truro Gas Company on the 27th ult., the Chairman (Mr. J. James), replying to a vote of thanks accorded to the Directors, said it gave him considerable satisfaction to compare the Company now with what it was fifteen years ago. To-day it would bear inspection by any practical man. Fifteen years ago they were weak; now they were strong. They had faced many difficulties; but they tried for years to improve and strengthen their position. They had now transferred their leasehold into freehold property, and had put their buildings and plant into substantial condition. A great deal was due to their Engineer and Manager (Mr. S. J. Ingram) for the way in which he had carried out his work; and they owed very much to him for the satisfactory position in which the Company was to-day. He proposed a vote of thanks to Mr. Ingram and to the Secretary (Mr. W. H. Sainsbury). This having been accorded, Mr. Ingram, in reply, stated that the Company had 1500 consumers. Their output of gas had increased 2¾ million cubic feet during the year, which was more than many of the electric lighting companies in the district had for a total output. Mr. Sainsbury also replied.

GAS AND ELECTRIC LIGHTING AT WEYMOUTH.

Some interesting features of the gas supply of Weymouth were brought before the shareholders of the Gas Company by the Chairman (Mr. J. Geach Rowe), in moving the adoption of the report of the Directors at the recent half-yearly meeting. Mr. Rowe has succeeded to the position filled for about seven years by the late Mr. J. E. Robens, to whose memory he paid a fitting tribute—the deceased gentleman having been connected with the Company from the year 1867 to the time of his death. He then passed to the accounts for the six months ended the 30th of June, showing a disposable profit of £4974; the Directors reporting an increase of 1,272,100 cubic feet, or 2·23 per cent., in the quantity of gas sold in the first half of 1909. The Chairman remarked that it would be of interest to every shareholder, and encouraging to every consumer, when he stated that since the electric light was introduced the output of gas of the Company had gradually increased by the enormous total of 25 million cubic feet. With this continued, it would be the pleasure of the Directors in due time to further develop the scale of their service; and though they had lowered the price of gas from 3s. 6d. to 3s. per 1000 cubic feet during the period with which he was dealing, it might still be anticipated that the future would see further reductions. The extensions of the plant were nearing completion; and when they were finished the Company would be possessed of the most modern and efficient gas-works in the southern district.

The Chairman was followed by Mr. S. J. Fowler, one of the Directors, who also alluded to what the Company had done for the consumers since the introduction of the electric light. He said that in the first two years they took off in price no less than £1658, which was circulated and divided among all the consumers who burnt gas. After that, in 1906, they gave them a further allowance of £883. From 1907 to 1910 they took off another 2d., which brought the total to £3391 for the four years. Therefore from 1904 to 1910, they divided among the consumers the sum of £5932. He thought such a record as the Company had was evidence of the feeling existing between them and the town. They acknowledged the abounding support they had received from the town, and the more they had, the quicker would come the time when they would increase the £5932 bonus, and grant them a still further concession.

The report having been adopted, and a dividend for the half year at the rate of 5 per cent. per annum (less income-tax) declared, a vote of thanks was cordially passed to the Chairman and Directors, also to the Engineer and Manager (Mr. D. F. Colson) and the Secretary and Accountant (Mr. E. Y. Wood), for their services. Mr. Colson, in reply, said it was a pleasure to receive such votes of thanks after the work of each half year; and they appreciated the compliment most thoroughly. He would convey to the staff the shareholders' kind expressions of thanks. Mr. Wood, in acknowledging the vote on behalf of the secretarial staff, said it was very gratifying to know that they had done their best, and that the shareholders appreciated their services.

THE PUBLIC LIGHTING OF HARROGATE.

The Gas Company and the Corporation.

A large portion of the speech of the Chairman of the Harrogate Gas Company (Mr. F. Barber), when moving the adoption of the Directors' report at the half-yearly meeting of shareholders on Monday last week, was devoted to a criticism of the action of the Corporation in regard to the electric lighting contract. The facts connected with this matter were given pretty fully, and commented upon, in the "JOURNAL" for the 24th of May; and therefore it is not necessary to follow Mr. Barber through the details of his speech, which were necessary for the information of the proprietors. A few points may, however be noticed. It will probably be remembered that, acting on the understanding that the Public Lighting Committee had had submitted to them by the Electricity Department of the Corporation a scheme for lighting by electricity the whole of the public lamps then lighted by gas, the Company submitted five alternative schemes for the better lighting of the town by their illuminant, at an inclusive annual cost. They were based on the whole of the public lamps being lighted by gas; and this meant the conversion of 321 electric lamps into gas-lamps. The annual sums for which the Company offered to carry out the schemes were: A, £3686; B, £3737; C, £3937; D, £4020; and E, £4122. Had the offer been accepted, the Corporation would at once have effected an annual saving of £543, £432, £232, £149, or £47, according to the one selected. Scheme A would have saved the town a sum equivalent to a rate of 1d. in the pound. The C, D, and E schemes were never compared with the scheme eventually adopted, because, as the Chairman of the Lighting Committee stated in the Town Council, the B scheme was taken for comparison, "as it presented to them the minimum of the requirements, and would compare with the scheme prepared by the Electrical Engineer." After the Company's B scheme appeared in the Press, it turned out that the Corporation scheme only proposed to replace existing gas-lamps with 69 electric lamps, giving from 45 to 50 candles—the standard of the present upright incandescent gas-lamps—against a minimum light of 65 candles to be provided under the Company's scheme, with an illuminating power for the larger lamps greater than any substituted for the old arc lamps. The meaning conveyed by the Chairman's speech was, said Mr. Barber, in direct contradiction of these facts. He then made a comparison between the Company's B scheme and their Electrical Engineer's "original scheme;" but he did not state what this scheme was. Mr. Barber said that he could not, therefore, check his figures; but he undertook to say this, that if his conclusions as to the comparative cost of gas and electricity were true, he was not paying cost price for his electricity. Having dealt with other figures, Mr. Barber said that in the result the whole of the Company's schemes were rejected; and he thought the Chairman of the Committee reserved till the end of his speech the true reason for their rejection when he said: "The Committee felt a great reason for refusing the Gas Company's scheme was on account of the certain damage that would be done to the town's electric lighting undertaking, which had been extremely profitable to the ratepayers. He thought he need not labour the argument that if they handed over to the Gas Company the whole of the lighting, which the town had installed at a considerable cost, the Company would naturally use that as a tremendous lever and advertisement, and they would suffer in the private house supply." This he (Mr. Barber) thought gave away the case of the Corporation. All the Company's schemes offered more light than that now to be furnished, with an immediate substantial saving to the ratepayers, and they were rejected in favour of a scheme for less light at a cost of £150 a year on capital and of 1¼d. per unit on every unit of electricity used. The Chairman of the Electric Lighting Committee claimed that his undertaking should be supported because out of the profits of it £1745 a year had been applied to a reduction of rates; but he (Mr. Barber) put forward a similar plea on behalf of the Gas Company, on the ground that their annual local rates within the borough amounted to £2069, and there was the prospect of a considerable increase. He protested against the hostile attitude of the Corporation towards the Gas Company, as shown by their decision to ask their Member of Parliament to oppose the Standard Burner Bill. The motive underlying this opposition was clearly, therefore, to prevent perfectly legitimate trade competition upon the part of private gas companies, by binding them to obsolete methods, and so preventing them giving to their consumers the fullest advantages of the modern improvements in the means of illumination by gas.

PUBLIC LIGHTING OF WESTMINSTER.

Reply by Mr. Goodenough to the Secretary of the Electric Lighting Company.

"The Times" last Wednesday contained the following letter by Mr. F. W. Goodenough, the Controller of the Gas Sales Department of the Gaslight and Coke Company, in reply to the statement by Mr. E. W. Seale, the Secretary of the Charing Cross, West End, and City Electricity Supply Company, Limited, given in the "JOURNAL" for the 30th ult. (p. 596).

The statement issued by the Charing Cross, West End, and City Electricity Supply Company respecting the pending displacement of electricity by gas in the West-End needs little comment. The facts speak for themselves. It is because the electric light contracts for the Strand and St. George's districts (as mentioned by those seeking to minimize the victory of gas) "do not expire for some years" that gas is, for the present, only displacing a portion of the arc lamps in Westminster. It has been officially stated that the St. George's electric light contract costs the city £10,000 a year more than would efficient gas lighting.

The tenders which led to the recent victory of gas compared as follows (*vide* report of Works Committee):—

Gas	£13,800 per annum.
Electricity	21,800 ,,

When tenders were invited for the lighting of Aldwych and Kingsway—a new thoroughfare in which new mains had to be laid by whichever party obtained the contract—the comparison of prices (for equal candle power) was—

Gas	£15 per lamp per annum.
Electricity.	27 ,, ,,

The electricians are welcome to all the consolation they can derive from their amusing calculations as to the price obtained for gas. To see them holding up their hands in horror at (assumed) differential prices charged by a supply company is to be reminded irresistibly of "Satan rebuking sin." When the St. James's Company reduced their price five years ago from £30 to £17 per arc lamp per annum to keep out gas from their streets, I do not remember much being said by electricians about "considerations of advertisements and preference" having "an undue bearing on the composition of the prices tendered."

ELECTRICITY SUPPLY AT HYDE.

Gas Company's Grievance.

At the Tramway Offices, Stalybridge, last Wednesday, Mr. M. K. North, M.Inst.C.E., held an inquiry into an application to the Local Government Board by the Stalybridge, Mossley, Dukinfield, and Hyde Joint Tramway Board for permission to borrow £22,268 for electricity purposes. The application was opposed by the Hyde Gas Company, who were represented by Mr. Brocklehurst.

The Clerk to the Board (Mr. Schofield) explained the objects of the loan. In the first place, £15,000 was required to meet anticipated expenditure for mains to March 31, 1912—a sort of reserve fund for three years, and less balance unexpended from the previous sanction, which amounted to £5192; leaving the amount of the application £9808. Secondly, the loan was to meet anticipated expenditure for transformers to 1912 of £5000, less £2832 balance unexpended from previous loan; leaving £2168. In this case they proposed to make application for £2100. Thirdly, they were making application for £968 for a coal elevator, conveyor, and bunkers. Fourthly, they required £1300 for mechanical stokers. With reductions, the application stood at £14,168. At the same time, they asked permission to be allowed to expend the remaining portions of loans previously sanctioned.

The Engineer (Mr. Blackmore) explained the technical details of the works for which the loan was required, and he was subjected to a long cross-examination by Mr. Brocklehurst. In reply to the first question, he said there had never been a profit since the inception of the scheme, and the total losses in the last seven years came to £81,000. Dealing

with the electricity department, Mr. Brocklehurst asked if there was any immediate prospect of it becoming productive; and the witness replied that there was every prospect. This year there was only a loss of about £500; and it would be perfectly easy to make up this loss in the twelve months. Under their Act, the loss was divided by four, and each of the Corporations concerned paid an equal share.

"Yes," said Mr. Brocklehurst, "but have not the great body of ratepayers been financing the electricity undertaking for the advantage of a small number of consumers?" Witness replied: "I take it that this inquiry is for borrowing money to give the whole of the ratepayers the advantage of a cheap supply. Any money the Board spend is upon a commercial basis. We do not spend money unless it is for the benefit of the ratepayers generally." Witness was next asked if he pledged his word that the electricity undertaking was going to be remunerative next year; and he replied that he did. Mr. Brocklehurst proceeded to question witness as to the prices charged for lighting and motive power purposes; and Mr. Blackmore, in the course of his answers, said the cost of electricity for the tramways undertaking was 0·825d. per unit—the lowest in the kingdom; and they could produce electricity 80 per cent. cheaper than Manchester. They had put by £25,000 as a sinking fund in reduction of their debt; but should they happen to have a fire at the works, they would have to renew out of the ratepayers' pockets. They laid a main at a cost of £905, and had a revenue of about £250 per annum from it.

At this point, the Inspector asked Mr. Brocklehurst why he was objecting to the application. In reply, he said it was extremely difficult to take objection to any particular item, because they had no information as to the mode in which the money was to be spent. All they were informed was that £22,268 was to be applied for. He found, on coming there, that the exact figure was £14,168. This was all the information they had supplied him with; so that in coming there to object he had to deal with the question on general grounds. In the past the undertaking had been launched upon estimates which had proved unsound, and which were enormously exceeded; and in consequence of the high charges upon capital, and of deficits shown year by year, it would be advisable for the Board, instead of launching out into new expenditure, to endeavour to make past outlay remunerative. This was the basis of his general criticism; and he hoped he had been able to make this view of it perfectly clear. Every year since its inception the undertaking had been a burden upon the ratepayers. He would also call attention to the small number of consumers as compared with the1 9,500 ratepayers, who from the commencement had been asked to pay, through the medium of the rates, for the cost of providing electricity to 415 consumers of electricity supplied at less than cost price. They (the objectors) considered it bad finance that there should be no provision made for contingencies in the current accounts—that there should be no depreciation fund. They did not think, having regard to the life of electricity undertakings and the dangers of them, that a sinking fund was sufficient to pay off all the financial liabilities. He was instructed by the Hyde Gas Company to appear before the Inspector with a feeling of grievance. The Company were large ratepayers. In the borough of Hyde alone they had a rateable value of nearly £4000; and in one sense they were interested parties, because they found that the Electricity Department of the Joint Board competed with them in lighting, and the Company, as ratepayers, had to pay, through the medium of their rates, to enable the Board to do this. The Company had to finance the Board, so to speak, to supply electric lighting at less than cost price. It did seem to the Company a little hard that they should be compelled to contribute, through the medium of their rates, to financing what was undoubtedly a rival undertaking, which, if it had not been supported out of the rates, would have been wound up before this.

The inquiry then closed.

RHYL GAS AND WATER SUPPLY.

A recent number of the "Rhyl Record and Advertiser" contained an article showing the development of the town in the past twenty years; and in it the following particulars are given in regard to the gas and water supply.

The gas-works were originally in the hands of a company; but in 1893 they were acquired by the Improvement Commissioners for £35,000. The capacity of the works was about 25 million cubic feet per annum; the sale of gas being less than 20 millions. Additions and improvements have been made at a cost of £18,000; and the works are now quite up to date—the plant being equal to a make of 80 millions per annum. Notwithstanding this expenditure, the payments for interest and the redemption of loans have been brought down from 1s. 6d. to less than 11d. per 1000 cubic feet of gas. The annual income at the time of purchase was about £5000; now it is £12,000. The price of gas has been reduced from 3s. 6d. to 3s. per 1000 cubic feet. In 1903, the profits were £796; whereas for the past financial year they were £1782. The working results have each year improved on those of the preceding year. The total expenditure on the works to date is £53,986. The present value of the undertaking, based on 28 years' purchase of the gross profits, may be put down at £125,000; and in slightly more than twelve years the original purchase-money will have been redeemed.

The water-works were acquired in 1893 for £74,000; and they were found to be in a very defective condition. Since then the authorities have been engaged in a continuous struggle to get them into good order. Works of various kinds were carried out at a cost of £24,000; but they did not increase the storage, which was totally inadequate. In 1901, the Urban District Council promoted a Bill, and obtained powers to construct another reservoir on the watershed; and after considerable engineering difficulties, the works were completed in the autumn of 1905; the cost being about £26,000. Since then the only addition of importance to the works has been a water-tower, completed last year, the effect of which has been to give the town constant pressures during the present season. The total expenditure incurred since the purchase of the works has been £52,000; making, with costs and the original sum, a total outlay of £136,000. There has been a steady growth in the income. At the time of the purchase of the works, it was only £4500 per annum; whereas in the past financial year it was £8500.

It only remains to say that all extensions and improvements, including the new reservoir, since both the gas and water works have been owned by the District Council, have been designed and carried out by the Gas and Water Engineer, Mr. Leonard G. Hall, Assoc.M.Inst.C.E., who has most successfully conducted both undertakings.

GAS AND ELECTRIC LIGHTING IN THE FAR EAST.

Success of Gas in Japan.

In the "JOURNAL" for the 16th ult. (p. 480), reference was made to the prospective extension of gas supply in the south of Japan. The following remarks on the position of gas and electric lighting in the Far East appeared in the "Financial Times" last Tuesday.

In every part of the world, beginning from London, gas seems to be making headway over electricity, while at one time it was feared that with the advent of electric lighting gas for illuminating purposes would be a thing of the past. Of course, there are advantages in the one system which are not to be found in the other, and *vice versâ*. The very fact that in the squares and prominent streets of London gas lighting is being substituted for electric lighting, goes to prove that gas has certain elements in it which make it advantageous for use as an illuminant for public places. . . . In the East, gas and electricity are equally well patronized, excepting in Japan, where certain conditions go to make the use of gas more convenient. In Japan there was a run for electric enterprises, and electric lighting was decidedly in popular favour some time ago. Now it appears that the tables have been turned, and no less than nineteen companies have been formed for gas manufacture in the provinces, not including the Chiyoda Gas Company, which is to compete with the Tokyo Gas Company. The following is a list of the provincial towns in Japan where gas-works have been commenced, or companies founded or are to be founded in the near future:—

Place.	Capital. Yen.	Place.	Capital. Yen.
Shimonoseki	350,000	Yamada	300,000
Kumamoto	500,000	Hamamatsu	500,000
Kagoshima	500,000	Shizuoka	500,000
Omuda	300,000	Moji	300,000
Fukuyama	300,000	Sendai	600,000
Himeji	500,000	Okayama	250,000
Takamatsu	500,000	Kure	300,000
Niigata	500,000	Kofu	300,000

FATALITY TO A SHEFFIELD GAS WORKMAN.

A Surprising Verdict.

On Monday last week, an inquiry was held at Sheffield, by Mr. D. Wightman, into the circumstances attending the death of Robert Baker (59), a workman employed at the Grimesthorpe station of the Sheffield United Gas Company.

According to the evidence given by the Superintendent of the works (Mr. J. Hubert Wright), deceased was a general labourer, and about once a week, for the last four or five years, he had been called upon to empty drums of hydrocarbon oil; and neither he nor any of the men similarly employed had complained. On the 17th of August, Baker was told to empty three 100-gallon drums; and on his completing the task, he complained of illness. After being walked about, however, he recovered sufficiently to walk home, with the assistance of ambulance men. Seeing him at the works on the 20th, Mr. Wright asked him when he was likely to begin again; and he said he did not feel very strong, and thought he would take a few more days off duty. Witness never again saw him alive. Mr. Wright explained that there was no poisonous gas in the oil contained in the drums; but on the 17th of August the deceased was more exposed to the fumes than the other men. He could only suppose that these getting on the man's lungs had affected his heart; for no ordinarily healthy man would be troubled.

The person with whom the deceased lodged was called, and stated that he had complained of pains in his chest after having emptied the drums, and on the last occasion had consulted a doctor, who said the gas was "all over him." She was followed by Dr. Frank Hardy, who had made a postmortem examination of the body, and said he found extensive pleurisy. The blood was fluid everywhere, and was a bright red cherry colour, which suggested to him the possibility of the presence of carbon monoxide. The actual cause of death was failure of the heart's action brought on by a pleural effusion. The heart was displaced in consequence, and its action was bound to be embarassed owing to the man going about when he ought to have been in bed. In answer to Mr. E. W. Clegg, who appeared for the Gas Company, witness said Dr. Sinclair White agreed with him in believing that a case had never been known in which so long a time as nine days had elapsed before a man who had inhaled carbon monoxide in deadly doses had expired. The usual time was one or two days. There was no reason why Baker should not have recovered from the pleurisy if he had received proper treatment.

The Coroner said the Jury could only return a verdict that Baker had died from pleurisy, and leave the question of carbon monoxide to the legal representatives and the Gas Company. If the jury pleased, they could say that death was due to carbon monoxide poisoning, though the evidence did not warrant it.

The Foreman said that while the Jury respected the medical evidence, they were still of the unanimous opinion that Baker's death had been hastened; and they returned a verdict of "Death from pleurisy accelerated by gas fumes."

FATALITY ON THE MANCHESTER PIPE-LINE.

Alleged Suffocation by Varnish Fumes.

An accident which raises the question of the liability of water engineers in the carrying out of large contracts has occurred on the Thirlmere pipe-line of the Manchester Corporation, in the vicinity of Caton, 4 miles east of Lancaster. The precise spot is the Conder syphon near the Cragg Wood. At present, as readers of the "JOURNAL" are aware, the Manchester Corporation are laying down their third line of pipes from Thirlmere. It extends about 96 miles, of which 45 miles are pipes chiefly 44 inches in diameter, 36¾ miles are "cut-and cover," and 14¼ miles tunnels. While the new pipe is being laid, the older pipes are cleaned out. The Contractor for the Caton length is Mr. J. Moffat, of Manchester; and his specification required that the joints and bevels of the old pipes should be cleaned and blackened with varnish approved by the Engineers of the Corporation. A sample of the black varnish was passed before the order was given for it; and since the contract began, a quantity has been kept in the stores.

Last Tuesday, a young labourer named Mistlethwaite, of Caton, was told by a ganger, George Bennett, to clean out a length of pipes; and next day he was ordered to black varnish the joints and bevels 110 yards from a manhole. He started at 6.30 a.m.; but as at half-past eight he did not respond to the call for breakfast, a youth named Bridges was told to go and see what was the matter. When he had gone 50 yards up the pipe, he detected the smell of varnish; and when he got 100 yards up, he found Mistlethwaite lying unconscious. He turned him over, and then went back to the manhole for assistance. The ganger Bennett and James Dennison accompanied him up the pipe. They all felt the effects of the varnish fumes, and with difficulty brought the body of Mistlethwaite down to the manhole, where all the men collapsed. By the aid of artificial respiration the three forming the rescue party rallied; but Mistlethwaite was quite dead.

These facts were borne out at the inquest held by the Lancaster Coroner (Mr. Holden) on Thursday. Dr. Bingham, who made the postmortem examination, said there was evidence in the brain and heart that the man died from asphyxiation. It was dangerous to have to work in varnish fumes in a confined place 110 yards away from a manhole. A pungent odour was emitted from the varnish; and he had no doubt the man died from suffocation by the fumes. Alexander King, the foreman, said deceased was employed on similar work the previous week; and other men had done it for twelve hours. It was a great surprise to them that there was any danger in using the varnish. The deceased worked five chains from a manhole, and other men had worked thirteen chains. Dr. Bingham remarked that there was more ventilation there—a 10-inch air-valve. Witness said the varnish was in store and approved by the Manchester Engineers before he came on the job. The Coroner examined a tin of the varnish, and said it was very strong. Mr. Tilly (for the relatives) asked if there had ever been complaints about the varnish before. Had men been overcome by the fumes? Witness replied that they had had complaints from gangs about the smell of the varnish.

The Coroner said it was evident they could not carry the inquiry further that day, because they had not had responsible witnesses before them, who had given orders for the varnish to be used. They must adjourn, and see whether the varnish was fit to be employed, and who was responsible for its use.

The inquest was adjourned till the 14th inst.

FINANCES OF THE METROPOLITAN WATER BOARD.

Possibility of a Deficiency Rate.

In view of the present financial position of the Metropolitan Water Board—the accounts for the year 1909-10 showing a large deficiency following upon one for the preceding year—there is a prospect of the power of the Board to levy a deficiency rate being put in operation. Indications are not wanting that such an action would be opposed by the London County Council, who have lately given publicity to the following report on the subject.

There are certain features which have an important bearing on the question of the need for levying a deficiency rate, but with which the Water Board may perhaps not deal, except at the instance of the Council, or unless further statutory powers are conferred upon the Board. We refer particularly to the inadequate contribution to the revenue of the Board which is made by the extra-London districts. It appears that London contributes to the domestic water-rate of the Board at least 50 per cent. per head of the population more than the outside districts, involving a very large additional burden upon London. Though we do not suggest that population is a suitable basis for water charges, this fact is some indication of the prejudicial effect upon London of the existing basis of charge for domestic supply. The basis of charge is not arrived at under the same law in London and the outside areas. The Valuation (Metropolis) Act, 1869, provides for a quinquennial revaluation of all properties in London. As an example of the importance of this revaluation to the Metropolitan Water Board, we may mention that the last quinquennial revaluation in London had the effect of increasing the Board's income by about £55,000 (less losses on collection), without any increase in expenditure. Outside London there is no regular revaluation of properties, and consequently no guarantee that the standard of assessment is kept up to date; nor is there any periodical increase of revenue from this cause. At the time of the passing of the Metropolis Water Act, 1902, it was estimated that the rateable value of premises for poor law purposes in extra-London was, on an average, 15 per cent. lower than the London standard. Before the Metropolitan Water Board (Charges) Act, 1907, the Board had power itself outside London to fix the basis on which it should charge. By this Act it was deprived of the power, and the immediate loss of revenue amounted to £26,800. The ultimate loss was more than this; and there seems little doubt that, if the standard of assessment were the same in extra-London as within London, the Board's revenue would benefit to the extent of between £40,000 and £50,000 a year. Such an additional income would have gone far to ease the financial position.

For the reason explained in the above report, the London Council are once more urging the Water Board to make "an inquiry into the effect on income of the use, as the basis of charge for domestic supplies, of rateable value determined according to two different standards of valuation respectively for London and the other districts within the Board's area."

SOUTH STAFFORDSHIRE WATER COMPANY.

Electricity v. Steam—The Proposed National Water Board.

The Half-Yearly General Meeting of this Company was held at the Offices in Birmingham last Wednesday—Mr. C. GABRIEL BEALE in the chair.

The Directors stated in their report that the number of houses laid on during the six months ended the 30th of June was 758; making the total supplied 138,938. The gross amount of water-rates for the past half year was £72,618, against £73,251 in the first half of 1909. There remained for distribution, after the usual provisions, £29,364; and a dividend at the rate of 6½ per cent. per annum (less income-tax) was recommended on the ordinary shares. The amount of this dividend being £20,894, £8469 would be carried forward. The Engineer (Mr. H. Ashton Hill, M.Inst.C.E.) reported that the machinery, plant, and buildings of the Company were in substantial order and repair.

The CHAIRMAN, in moving the adoption of the report, pointed out that, owing to various causes, there had been a great decrease in the trade water supplies, the returns from which had fallen off by £1462. This was not due to any general decline throughout the district, but to the fact that ten large customers had found other means of supplying themselves with water. Another circumstance which accounted for less consumption for industrial purposes was that a number of firms were using to an increasing extent electrical instead of steam power. The obvious result was that the motor came in and the steam-engine, which, of course, used large quantities of water, went out. Thus their water supplies in the Black Country had been influenced to some extent. The building supplies had fallen off only slightly; but on railways the reduction in the use of the Company's water was represented by the figure of £290. This was accounted for by the new working arrangement between the companies, which led to economies in traffic running. Rates and taxes showed an increase of £400. Every year such advances were met with; and on this occasion the larger amount was due chiefly to increased assessment in the Lichfield district. During the half year, £12,500 had been expended on works. This was due chiefly to the ordinary capital expenditure of the Company, which was always increasing as the district grew; but it was also in part due to compensation which they had had to pay under the Act of 1909. This Act was retrospective, and referred to works which the Company carried out years ago, and for which compensation for damage was not paid. For the past twelve months, the Board had been dealing with these claims. They had caused great anxiety; but the Directors now saw the end of them. The Company could issue fresh capital, confident in the knowledge that there were no further claims in the background which would be likely to disturb the prospects of the Company. The Board had reduced the dividend by one-half per cent. They proposed further to build up the capital by a moderate issue of stock, as there were two rather large commitments—an addition to the pumping-station near Wednesbury, involving a total expenditure of £13,000, and boring operations at Maple Brook. As to the Water Supplies (Protection) Bill, the Chairman said that in theory it was to protect the owners of small private supplies from the depredations of water companies and local authorities who absorbed large quantities of water. It was referred to a Joint Committee of the two Houses, and a great deal of evidence was taken; and in the result it was reported without amendment. This in itself looked alarming, because their Company would be seriously affected. But then the Committee went on to slaughter all the sections of the Bill. They said they were impracticable, and could not be worked. It might, therefore, be taken that the Bill was dead. But the important result of the Committee's investigations was that they had reported their conviction that the question of the water supply of the country should be thoroughly overhauled, with a view to the whole country being mapped out into areas under the control of Water Boards. This was a question of vast importance. Time after time it had been suggested by Committees and Commissions that, if the population were to continue increasing at the old rate, the means of conserving all possible means of obtaining pure water must be carefully considered. It was for investors in water undertakings to look to their position; but he did not think if Water Boards were established any injustice could be done to those companies who had complete and well-arranged undertakings. He did not think there need be any anxiety about this; but anyone who had had to do with supplying water to such areas as that of Birmingham could have no doubt as to the seriousness of the question, or the desirability of regulating water supply from a national rather than a local point of view. He was not apprehensive that the legislation on this would follow immediately; but if it came, and the Company had to be bought out, they might rely upon it that their successors would do the best they could for the then shareholders.

Mr. F. H. LLOYD seconded the motion; and it was agreed to unanimously.

The dividend recommended was then approved; and a vote of thanks to the Directors concluded the meeting.

Owing to a fault at one of the sub-sections of the Scarborough electric lighting system, the Londesborough Theatre, the Theatre Royal, and the Hippodrome were deprived of electric light for from fifteen to twenty minutes last Tuesday night.

WATER SUPPLY OF LONDON.

A Defence of the Metropolitan Water Board.

The Twenty-Fifth Annual Conference of the Sanitary Inspectors' Association was held at the Fishmongers' Hall, E.C., last week, under the presidency of Sir James Crichton-Browne; and on Friday, a paper was read by Mr. E. B. Barnard, the Chairman of the Metropolitan Water Board, on the "Water Supply of the Metropolis." It was to a large extent a defence of the Board.

Mr. Barnard traced the history of the events leading up to the formation of the Water Board, and, illustrating the magnitude of the task imposed upon them, said the population they were supplying with a necessary of life and trade was nearly equal to that of the two kingdoms of Norway and Sweden, about the same as the Dominion of Canada, 2 millions more than Australia and New Zealand put together, and larger by about a million than the whole population of Scotland and Wales. The average daily supply was upwards of 225¼ million gallons. If they could build a tank the size of Trafalgar Square (2½ acres), and the height of Nelson's Column, London would empty such a tank twice in every 24 hours. The average supply per head per day was 32 gallons, and in the summer 36 gallons, or a barrel of water every day per man, woman, and child in a population which represents 16 per cent. of that of Great Britain and Ireland. The water-mains alone would reach from Liverpool to New York and back again; and it would take the *Mauretania* ten days to race along the whole length.

Turning to the Board's financial position, Mr. Barnard said that in addition to the net debt of £47,003,000 with which they were endowed when they came into existence, they had to spend some £1,500,000 in new works of an imperative nature. Further, the Board were bearing an annual charge of £69,000 for superannuations, pensions, and compensation allowances to officers and servants of the Water Companies. This brought him to the subject of the attacks made upon the Board in connection with their revised charges. He said a new era began when these charges came into operation in April, 1908. He was unable to say what the ultimate effect of the equalization of water-rates would be. The Board might have to levy a deficiency rate; but it was yet too early to make any authoritative statement concerning it. Whatever the financial result of the Charges Act might be, the Board could certainly claim a large dividend in improved sanitation, so far as water supply affected it. Their charges were inclusive, and the irritating extras for sanitary necessities had been got rid of. They had reduced the charges for water for public purposes, including sewer flushing and road watering, to a figure only a little more than their net debt burden. The interest and rent charges of their capital debt amounted to nearly £1,500,000, equivalent to 4·3d. per 1000 gallons supplied; and they were letting the public authorities have water at 6d. per 1000 gallons. Their charges were low in comparison with those levied elsewhere; but because certain properties were not charged enough in the past and now suffered from an equalized charge, which Parliament deliberately levied, notwithstanding the most strenuous opposition of the parties affected, they heard of the sinking of wells in all directions. Railway companies, owners of valuable City properties, and others with large rateable values, were attempting to evade their charges for water supply, and in this way were ensuring the certainty of a deficiency. They avoided paying a water-rate; yet what would the Fire Insurance Companies be demanding of them if the Board's mains were not in the abutting streets fully charged with water? Supposing that some of these independent City properties were to catch fire, and there was no water in the mains, the imagination boggled at the extent of their indignant outcries. Why should the ordinary householder be taxed for their benefit?

Referring to the measures taken to ensure the purity of the supply, Mr. Barnard pointed out that since the Board came into existence and took over the works of the Water Companies, there had been an improvement in the quality and an increase in the quantity of water supplied. In the year ending March 31 last, more than 13,000 samples of water were examined, either chemically or bacteriologically, in the ordinary routine of the Board's work, exclusive of 1100 samples collected for special purposes. This led him to the subject of storage; and he pointed out that, in order to provide for the ever-growing demands made upon them, the Board had found it necessary to construct large reservoirs. These served a double purpose. Originally they were built solely with the idea of storing water when it was in abundance, so that it might be utilized in periods of drought. It was then found that water so stored greatly improved in quality; and an exhaustive series of experiments proved that storage reduced the number of bacteria of all sorts, devitalized the microbes of water-borne diseases, and reduced the amount of suspended matter. The discovery was made by Dr. Houston, the Board's Director of Water Examination, that if raw river water is artificially infected with millions of cholera vibrios, the vast majority die in storage within one week. In spite of the increased consumption of water, the Board had, by strict attention to waste prevention, reduced by nearly 1½ gallons the average quantity supplied per head daily. They had hopes of making even further reductions.

With regard to the future, Mr. Barnard said the Board had to face a daily increasing population within what was called Water London. Various schemes had been investigated, and the Welsh scheme had been ruled out on economic grounds. In the result, the Board had adopted what was known as the Staines reservoirs extension scheme, for the provision of additional reservoirs in that part of the Thames Valley. Here was an abundant supply—a waste product running by, belonging to no one, and only requiring to be impounded in order to serve more than one great public benefit. Calculations had been made to show that the water so impounded would last until 1941, with an estimated population amounting to 12 millions. This scheme, which possessed features presenting an overwhelming advantage over the Wales scheme, contemplated a capital expenditure of about £6,273,000, which would be spread over a number of years.

In conclusion, Mr. Barnard remarked: I think I have said enough to show that the Board started life with a lapful of difficulties, and that we have mastered them. We did not call ourselves into being; we did not incur the vast debt we have to carry; we did not create the disabilities we have laboured under. We have honestly tried to do our best; and though Parliament saw fit to handicap us in the ways I have indicated, I think that the assumption of so many responsibilities by the Board seven years ago has been a success. I have endeavoured to explain that the matter of our charges, which is, in point of fact, the sole subject of the attacks made upon us, marks a transition stage in our history, and that it will be cured in the interests of public equity and not of class favouritism, however powerful or spiteful. As regards the future, I hope that I have demonstrated to you, and through you to the general public, that the Metropolitan Water Board is alive to its onerous responsibilities, and has, so far as human foresight and human forethought can command, framed a policy which, on engineering, financial, and scientific grounds, justifies, and will continue to justify, the confidence of the myriad inhabitants of this huge Metropolis.

A vote of thanks having been proposed to Mr. Barnard, the President expressed his appreciation of the paper, which he said was an exceedingly able vindication of the policy of the Board the author represented. He thought, however, Mr. Barnard was rather sanguine in anticipating a reduced consumption. Water was the first essential of sound sanitation; and he did not think the domestic bath had yet reached its maximum.

Subsequently, on the invitation of the Water Board, the members of the Association left London Bridge Pier in a steam launch on a visit to the Board's works at Hampton. They were received by Mr. Barnard, and, under the care of several guides, inspected the reservoirs, filter-beds, intakes, and pumping machinery.

NOTES FROM SCOTLAND.

From Our Own Correspondent.

Saturday.

A Special Committee of the Glasgow Town Council, which was appointed to inquire into any process of gas making which would produce a form of coal residue available for use in ordinary domestic grates, have recommended: (1) That the Gas Engineer be instructed to proceed with his experiments with steam-quenched coke and "Coalexld;" (2) that the Engineer be authorized to supply this for use in ordinary domestic grates; and (3) that an exhibit of "Coalexld" be sent to the forthcoming Smoke Abatement Exhibition, with a view to orders being obtained for it.

The community of Dumfries has been greatly agitated over the appointment of a Gas Manager to succeed Mr. J. M. Smith, who has gone to Stirling. The Gas Committee recommended that Mr. S. Dickie, who has been joint Manager with Mr. Smith for several years, be appointed sole Manager. This recommendation has been carried; but there is much to take note of before that point is reached. A week ago, the annual report of the joint Managers for the year ending May 15 last was published. From the report, it appeared that the quantity of coal carbonized during the year was 11,442 tons, the average price of which was 13s. 9·39d. per ton. Benzol was used for enriching to the amount of 12,320 gallons. The average cost of coal and benzol per ton was 14s. 3·11d. In the previous year, 11,902 tons of coal and 7411 gallons of benzol were used, at an average price of 15s. 7·43d. Last year, the quantity of gas manufactured was 111,570,000 cubic feet, being an average of 9758 cubic feet per ton, against 112,547,000 cubic feet, at an average of 9456 cubic feet per ton. Gas sold last year amounted to 105,175,813 cubic feet, at an average of 9192 cubic feet per ton, compared with 104,096,717 cubic feet, at an average of 8746 cubic feet per ton. The increase on sales in the past year was 1,079,096 cubic feet. Gas was unaccounted for to the extent of 5·73 per cent., or 1·83 per cent. less than in the preceding year, and the lowest percentage of loss during the burgh's management of the works. Mains and service-pipes had been renewed or repaired at a cost of £692. A large number of meters were tested, and defective ones replaced by new ones, at a cost of £544. The reserve fund amounts to £3353, from which there falls to be deducted £2999 15s., being the balance of the renewal portion of the extension applicable to the reserve account. This leaves the reserve fund at £365. It would be advisable to again place £1500 to the reserve fund, which was allowed for in the estimates for the current year. The sulphate plant had been worked very satisfactorily. The net sums received for sales amounted to £1102—an increase of £39. After deducting annual depreciation, interest, and working expenses, the net profit on the Gas Department for the year amounted to £336. Tar had been sold to Messrs. W. G. Walker and Sons, of Ayr, at a slightly increased price. A tar-distilling plant was erected to meet the requirements of the burgh, and was giving every satisfaction. Acting upon the Manager's report last year, a deputation appointed by the Council, along with the Managers, visited several gas-works for the purpose of inspecting the various methods of carbonizing. Following upon their report, plans and specifications were prepared, and during the year a complete reconstruction of the retort-house had taken place. The old erection had been replaced by a substantial building, which was being fitted up with an up-to-date carbonizing system, together with stoking machinery and coal-handling plant of the most modern type. The plant is not yet ready for gas manufacture, but will be completed in time to meet winter requirements. New coal-stores (for which estimates have already been accepted) will be commenced as soon as possible, probably in the early spring. In the estimate for the current year, after allowing for interest, sinking and reserve funds, and all working expenses, it is anticipated that there will be a balance of £576. Although this would allow of a reduction of 1d. in the price of gas, the Managers thought it right to draw the attention of the Council to the fact that the sum of £786, being principal and interest on the new loan, was included in the estimate, and falls to be paid this year; whereas only a small return for the use of the new plant will be available this year to meet that sum. Next year the plant will, of course, be in full working order, and the full financial benefit will be received. On Monday evening, a crowded meeting of ratepayers, convened by Provost Lennox, on the requisition of the Citizens' Union, was held in the Town Hall to consider the subject of the gas manager-

ship. The meeting lasted for two-and-a-half hours, during which time a great deal was said, both for and against Mr. Dickie. The most significant of all the statements made was unmistakably that which was contained in a letter written by the late Mr. George Malam, the then Gas Engineer at Dumfries, some years ago, in support of an application by Mr. Dickie for an appointment as gas manager. In his letter, Mr. Malam stated that Mr. Dickie served his apprenticeship under him, and that he considered him specially qualified for the post. This represents Mr. Dickie in a capacity altogether different from that of clerk, which it has been the fashion of some to regard him as. As the result of the deliberations of the public meeting, a resolution was adopted, by a very large majority, to the effect that it would be in the best interests of the public that a skilled engineer be appointed along with Mr. Dickie as joint Manager. The amendment was simply a proposal to leave the matter in the hands of the Council. The Town Council met on Thursday evening, and had before them, among other business, the filling up of the vacancy. The resolution of Monday evening was read to the Council, and then Judge Thomson, the Convener of the Gas Committee, who characterized the Monday evening meeting as inconclusive, moved the recommendation of the Committee, that Mr. Dickie be appointed. Provost Lennox moved that they should advertise for a Works Manager and Engineer to act as joint Manager with Mr. Dickie. It was also moved that the subject be delayed for a month. After long discussion, Provost Lennox's motion was lost by 12 votes to 9; and then the motion to appoint Mr. Dickie was carried, as against delay, by 13 votes to 10. It was agreed to take up in Committee the question of appointing a works foreman.

The Aberdeen Corporation gas accounts, which are summarized in another column, contain a record of progress which is quite creditable to the management. A year ago, the price of gas was reduced by 1d. per 1000 cubic feet, which accounts for the decrease in revenue; but the make of gas has since gone up nearly 10 million cubic feet, which is quite satisfactory. The Gas Committee have resolved to continue the price of gas at 2s. 6d. per 1000 cubic feet for lighting, heating, and cooking, and 2s. 3d. for motive power.

A laudable effort is being made by Mr. W. Geddes, the Hon. Secretary and Treasurer of the Scottish Junior Gas Association (Eastern District) to extend the influence of the Association. The means adopted—that of issuing circulars to gas managers and others interested—is the most direct method of approaching probable candidates for membership. The circular might have enumerated, as part of the benefit to be derived from membership, the number of good things which fall in the way of those who take an active part in the work of the Junior Associations. The latest of these is found in the promotion of Mr. A. Masterton, who was the first President of the Eastern District, to be Engineer and Manager of the Edinburgh and Leith Corporations gas undertaking, in succession to Mr. W. R. Herring. With such prizes in store, the junior who does not associate himself with the Junior movement is assuredly standing in his own light. It is to be hoped that Mr. Geddes' effort will meet with marked success, and that there will be a large accession to the membership during the session, which, to judge from the syllabus which is published, bids fair to be an exceedingly interesting one.

The Helensburgh Town Council last night resolved to reduce the prices of gas by 5d. per 1000 cubic feet, making the price for ordinary consumers 2s. 11d., and for prepayment meter consumers 3s. 4d., per 1000 cubic feet. The reduction in price, it was stated, is equal to 3d. per £1 in the burgh assessments.

The Turriff Gas Company, Limited, have paid a dividend of 5 per cent., and have fixed the prices of gas at 6s. 3d. per 1000 cubic feet to ordinary consumers, and at 5s. 3d. for cooking, heating, &c.

The Wick Gaslight Company have paid a dividend of 6 per cent., and have reduced the prices of gas by 2½d. per 1000 cubic feet; making them 5s. 2½d. for lighting, and 4s. for cooking and power purposes.

The Kirkcudbright Town Council have let a contract for the supply and erection of a pump, pipes, and standards, for the conveyance of tar and liquor from the gas-works to the railway station, to Messrs. Stewarts and Lloyds, Limited, at £175. There is to be an annual payment to the Railway Company of the sum of 5s., as wayleave for the plant.

The following somewhat enigmatical statement was published in the "Dundee Advertiser" on Tuesday last, under the heading of "Cupar": "The lighting of Cupar was a subject that led to considerable discussion at the meeting of the Town Council last week, and with winter fast approaching it was not inappropriate that this question should have been brought up. In the long winter evenings, the town has not much to attract its citizens in the way of amusement, and well-lit streets would go a long way to make up for this much-felt want. Notwithstanding the higher rate which is being paid for lighting purposes, in the past it cannot be said that the streets of Cupar have been over-lighted; and it is to be hoped that the present move will have beneficial results. When it is pointed out that during the course of last year over 45 dozen incandescent mantles were destroyed, the wonder is that a proposal to enter into an arrangement with the Gas Company to do the turning on and turning off of the lights has not been given effect to sooner."

Miss Elizabeth Baddeley was suffocated in bed at Silverdale, Staffordshire, last Thursday, owing to the breaking of a gas-pipe. It is supposed that mining operations caused her house to subside, and that this broke the pipe.

The half-yearly conference of the Richmond Gas Stove and Meter Company, Limited, was held at their works at Warrington last Tuesday and Wednesday—Mr. Horace M. Thornton presiding. The forthcoming gas-fire season formed the chief topic for consideration. On the first evening, the representatives and Managing-Directors dined together; and, at the invitation of the Company, Mr. E. W. Smith, M.Sc., of Leeds University, and Chemist to the Gas Heating Research Committee, gave a *résumé* of the report presented to the Institution of Gas Engineers at the annual meeting in June. The heads of all the works departments were invited to be present; and a general discussion followed Mr. Smith's remarks.

CURRENT SALES OF GAS PRODUCTS.

Sulphate of Ammonia. LIVERPOOL, *Sept.* 3.

At the commencement of the week there was still a hardening tendency in the market, and a further small advance was scored. All August requirements having been covered, however, the tone has become quieter, though prices are maintained at the highest point reached. The values at the close are £12 6s. 3d. per ton f.o.b. Hull, £12 7s. 6d. per ton f.o.b. Liverpool, and £12 8s. 9d. per ton f.o.b. Leith. No new business has been reported for future delivery; buyers evidently being disinclined to operate ahead at the level of prices now attained.

Nitrate of Soda.

The market for this article continues very firm; but no further increase in values has taken place, and the quotations on spot remain 9s. 4½d. per cwt. for ordinary and 9s. 7½d. for 96 per cent. quality.

Tar Products. LONDON, *Sept.* 5.

The markets for tar products have been fairly steady throughout the past week. Pitch has shown signs of further improvement, and the improved prices have been paid. Creosote is steady, and there is a fair amount of inquiry for export. Benzols remain unchanged. Crude carbolic is still of very little interest.

The average values during the week were: Tar, 19s. to 23s., *ex* works. Pitch, London, 38s. to 38s. 6d.; east coast, 38s. to 38s. 6d.; west coast, 36s. 6d. to 37s. f.a.s. Mersey ports. Benzol, 90 per cent., casks included, London, 6¾d. to 7d.; North, 6d. to 6½d.; 50-90 per cent., casks included, London, 7¾d.; North, 7d. to 7½d. Toluol, casks included, London, 10d.; North, 9d. to 9½d. Crude naphtha, in bulk, London, 3½d. to 4d.; North, 3½d. to 3¾d.; solvent naphtha, casks included, London, 1s. 1½d. to 1s. 2d.; North, 1s. to 1s. 1d.; heavy naphtha, casks included, London, 11d. to 1s.; North, 10d. to 11d. Creosote, in bulk, London, 2½d. to 2⅝d.; North, 2d. to 2¼d. Heavy oils, in bulk, 2¾d. to 2⅞d. Carbolic acid, 60 per cent., casks included, west coast, 1s.; east coast, 1s. 0½d. Naphthalene, £4 10s. to £8 10s.; salts, 40s. to 42s. 6d., bags included. Anthracene, "A" quality, 1½d. per unit, packages included and delivered.

Sulphate of Ammonia.

There has been a further slight improvement in this article during the past week, and prices are a little better in nearly all parts. Actual Beckton to-day is quoted at £11 15s. to £11 16s. 3d. Outside London makes are £11 10s. In Hull, the price is £12 5s.; Liverpool, £12 5s.; Leith, £12 8s. 9d. to £12 10s.; and Middlesbrough, £12 5s. to £12 6s. 3d.

A Trade correspondent writes: During the past week the prices of pitch have considerably improved, and the equivalent to 40s. 6d. Liverpool has been paid. There is a fair demand for creosote, and prices are about the same. Solvent naphtha is in great demand, and prices need not fall. Crude carbolic acid continues in about the same position. The average values for the week are: Pitch, 40s. London, 40s. east coast, and 40s. 6d. per ton Liverpool. Benzol, 90 per cent., 7d. per gallon, casks free; 50-90 per cent., 7¼d. per gallon, casks free. Toluol, 9¾d. per gallon, casks free. Crude naphtha, 3¼d. per gallon, naked. Light oil, 3½d. per gallon, naked. Creosote, 2¼d. to 2⅜d. per gallon, in bulk. Heavy oil, 3¼d. per gallon. Carbolic acid, 60's, 1s. per gallon.

COAL TRADE REPORTS.

Northern Coal Trade.

The coal trade shows ease, and for some kinds of coal the prices are a little lower—the production at the present time being very heavy. In the steam coal trade, best Northumbrians are about 9s. 9d. to 9s. 10½d. per ton f.o.b.; second-class steams are about 9s.; and steam smalls from 5s. 6d. to 6s. 9d. The shipments are fair for this season. In the gas coal trade, the demand is now steadily increasing for home consumption, and the quantities sent to the great Companies in the South are heavier; while the exports are tolerably good. Durham gas coals vary in price from 9s. to 9s. 9d. per ton f.o.b. for the usual classes, according to quality; while for "Wear" specials, up to 10s. 6d. is quoted. There are not many large contracts now in the market, but some sales are being made for delivery over next year at some of the ports of the Mediterranean. The prices offered are from 15s. 5d. to 16s. 5d. per ton delivered at Genoa; but there is still a little hesitation about the acceptance of such prices by coalowners, who have sold at times a considerable part of their output, while the buyers look to a plentiful supply of some classes of gas coal. Coke is steady; but gas coke is in increasing output, and may now be quoted from 15s. to 15s. 3d. per ton f.o.b. in the Tyne.

Scotch Coal Trade.

The market continues in a dull state. Coal for export is in poor request, and the home demand is far from brisk, except for smaller sorts. The prices now quoted are: Ell, 8s. 9d. to 10s. per ton f.o.b. Glasgow; splint, 9s. 6d. to 9s. 9d.; and steam, 9s. to 9s. 3d. The shipments for the week amounted to 333,157 tons—a decrease of 6934 tons upon the preceding week, and of 32,567 tons upon the corresponding week of last year. For the year to date, the total shipments have been 10,631,480 tons—an increase of 877,523 tons.

The profits of Messrs. Read Holliday and Sons, Limited, of Huddersfield, for the year ended the 30th of June were £35,021, and £3173 was brought forward. Of the total, £500 has been added to the private insurance fund, and £16,923 appropriated for depreciation. Debenture interest absorbs £2740, and a dividend of 10 per cent. is proposed on the ordinary shares—adding to the reserve fund £2000, and carrying forward £6167.

Aberdeen Corporation Gas Accounts.

The accounts of the Aberdeen Corporation Gas Department for the year ending July 31 have been made up and issued. They show a total revenue of £121,049, a decrease of £1588. Gas and meter rents produced £92,417, made up as follows: Ordinary consumers, £73,835; motive power, £6694; prepayment meters, £11,887; and meter-rents, £27. Residual products realized £26,041 (coke, £15,498; and tar and liquor, £10,543); house-services, £817; gas-stoves, £1610; and rents and feu-duties, £132. The expenditure amounted to £98,076—a decrease of £1808. The balance to net revenue amounts to £22,972, as compared with £22,753 a year ago. Coal cost £53,094, as compared with £94,976. Oil and coke for carburetted water gas cost £6056; and purifying materials, £1436. The salaries of the gas engineer, analyst, and the officers at the works amounted to £983; the wages of stokers and labourers, to £12,054; and the maintenance of plant, to £4845. The total expenditure in the manufacture of gas was £79,679; while the outlay on distribution was £4909. Gas-stoves cost £1689, to which there is added £898 of wages and other expenditure; and there is written off £790 for depreciation. Rents, feu-duties, and taxes amounted to £4367; management, to £1962; and discount and bad debts, to £3955. Annuities paid came to £4063; and interest on mortgages, bank accounts, reserve fund, &c., to £4052. There was carried to sinking fund for redemption of mortgages £10,259; for redemption of annuities, £650; and to the reserve and fire insurance fund, £300. There is placed to the renewal fund £3000; and £648 is to be carried to the current year's account. During the year, 69,424 tons of coal were carbonized; the yield of gas from which was 632,597,000 cubic feet. Of carburetted water gas, 112,178,000 cubic feet were made. Gas accounted for totalled 745,861,000 cubic feet; and gas unaccounted for, to 48,914,000 feet—equal to 6·15 per cent., as compared with 5·96 per cent. in the preceding year. The prices charged for gas were 2s. 6d. and 2s. 3d. per 1000 cubic feet.

Waltham Abbey and Cheshunt Gas Company.—Owing to depression in trade and the large number of empty houses in the district of this Company, there was only a small increase in the gas consumption in the six months ended the 30th of June. There was nevertheless a profit of £3168 available for distribution; and at the recent half-yearly meeting dividends at the rates of 8½ and 6½ per cent. per annum were declared. These, with the debenture interest, required £2442; and left a balance of £726. The whole of the plant had been well maintained by the Engineer and Secretary, Mr. W. Bince Randall.

Guiseley District Council and the Water Supply.—At the meeting of the Guiseley District Council last Wednesday, a long discussion took place on a resolution brought forward by Mr. Gladwin pledging the Council to "make a full inquiry into the question of the water supply, with a view to purchasing the same in the interests of the ratepayers." This proposition, which related mainly to the supply of the Guiseley Water Company, was ultimately withdrawn in favour of one inviting the Yeadon and Rawdon Councils to meet the Guiseley Council in conference, for the purpose of discussing the question of the joint purchase of the undertakings of both the Yeadon and Guiseley Companies.

Tiverton Gas-Works.

Mr. H. S. Bidwell, a Local Government Board Inspector, conducted an inquiry at Tiverton, last Wednesday, into an application by the Town Council for leave to borrow £4000 for purposes of the gas undertaking. The statistics submitted showed that the area of the borough was 17,680 acres; the population last census, 10,382; the estimated present population, 10,700; the gross estimated rental of the parish, £68,084; the rateable value, £57,438; the assessable value, £41,816; the district rate, 3s. 4d. in the pound; the poor-rate, 3s. 2d.; and the product of a penny on the district rate, £160. It was explained that the loan was required, in respect of gas-works, for regenerative settings and other items, which the great expansion of business in the past two years had rendered necessary, and which results had justified. The amount included £200 overspent on a loan sanctioned in 1906. The period of repayment of the original loan in 1897, under which the gas-works were taken over by the Council, had about half expired. The Borough Surveyor (Mr. J. Siddalls), replying to the Inspector, said that there was no competition at present with electric light. The Council had no intention of establishing electricity works, as it was found cheaper to do the public lighting with gas. The present annual cost of street lighting was £2 17s. per lamp of about 60-candle power. The Gas Manager (Mr. Clark Jeffery) explained that the new settings would effect a saving of about £150 per annum in labour and repairs. The works would also then manufacture 500 cubic feet more gas per ton of coal than under the old system. The price of gas was now 3s. 6d. per 1000 cubic feet; and the cost of coal delivered was about £1 per ton. Mr. J. Thorne (the Chairman of the Lighting Committee) remarked that, though practically the same amount of gas was manufactured last year as previously, the sales were 800,000 cubic feet more, giving a gross profit of £500. This was attributed, in great measure, to the new regenerative retorts, which had been in use for about six months. The Council were able to make a contribution of £443 to the rates. The price of gas when the works were taken over was 4s. 3d. per 1000 cubic feet. The present charge of 3s. 6d. compared favourably with other towns, particularly Taunton, where the price was 3s. 9d., though the output of gas was nearly double. Mr. W. H. Martin (a member of the Council) spoke in favour of the surpluses of profit from time to time being devoted to the extinction of the debt, instead of being placed to the borough fund. The Inspector paid a visit to the works which have been carried out or are in contemplation.

Leeds Water-Rates.—At the meeting of the Leeds City Council this week, a resolution will be submitted having for its object the increase of the water-rates of the city by about 35 per cent. The effect of the change, it is pointed out, is bound to be a serious one for all concerned; though manufacturers and other users of large quantities of water for business purposes will be hit the hardest. The justification put forward is the great cost of the new water-works at Leighton. A large annual sum will now have to be found for interest and sinking fund in respect of these works; and to meet this, it is proposed to derive an additional annual income of about £55,000 from increased charges. Under this arrangement, there will still be left the annual surplus of about £15,000 to be devoted to the relief of the rates.

GAS COMPANIES' STOCK AND SHARE LIST.

Referred to on p. 635.

Issue.	Share.	When Dividend.	Dividend or Dividend & Bonus.	NAME.	Closing Prices.	Rise or Fall in Wk.	Yield upon Investment.
£			p.c.				£ s. d.
1,474,000	Stk.	Apl 1	5	Alliance & Dublin Ord. .	81–84	+1	5 19 1
310,000	Stk.	July 14	4	Do. 4 p.c. Deb.	97–99	..	4 0 10
200,000	5	May 12	7	Bombay, Ltd. . . .	6¾–6¾	..	5 7 7
40,000	5	..	7	Do. New, £4 paid .	4⅝–5⅛	..	5 9 3
50,000	10	Aug. 31	15	Bourne- mouth Gas and Water } A 10 p.c. . . B 7 p.c. . Pref. 6 p.c.	28½–29½* 16–16½* 14⅞–15⅛*	..	5 1 8 4 4 10 3 18 8
311,810	10	..	7				
75,000	10	..	6				
380,000	Stk.	Aug. 12	12½	Brentford Consolidated	246–249	..	5 0 5
330,000	..	..	9½	Do. New . . .	184–186	..	5 2 2
50,000	..	..	5	Do. 5 p.c. Pref. .	—	..	—
206,250	..	June 10	4	Do. 4 p.c. Deb. .	93–101	..	3 19 3
220,000	Stk.	Aug. 31	11	Brighton & Hove Orig.	209–212*	..	5 3 9
246,320	..	..	8	Do. A Ord. Stk. .	150–153*	+1	5 4 7
460,000	20	Apl. 1	16⅝	British	44½–45½	..	4 13 5
109,000	Stk.	Aug 11	6	Bromley, A 5 p.c. . .	117–119	..	5 0 10
165,700	..	..	4½	Do. B 3½ p.c. . .	88–90	..	5 0 0
82,478	..	..	5½	Do. C 5 p.c. . .	106–108	..	5 1 10
55,000	..	June 29	3½	Do. 3½ p.c. Deb. .	85–87	..	4 0 6
250,000	Stk.	..	4	Buenos Ayres 4 p.c. Deb.	97–99	..	4 0 10
100,000	10	—	—	Cape Town & Dis., Ltd.	3–4	..	—
100,000	10	—	—	Do. 4½ p.c. Pref. .	5⅛–6⅛	..	—
50,000	50	May 3	6	Do. 6 p.c. 1st Mort.	49–50	..	6 0 0
100,000	Stk.	June 29	4½	Do. 4½ p.c. Deb. Stk.	88–90	..	5 0 0
157,150	Stk.	Aug. 11	5	Chester 5 p.c. Ord. . .	109–111	+½	4 10 1
1,513,280	Stk.	..	5⅛	Commercial 4 p.c. Stk. .	105–107	..	4 17 2
560,000	..	..	5	Do. 3½ p.c. do. .	101–103	..	4 17 1
475,000	..	June 29	3	Do. 3 p.c. Deb. Stk.	80–82	..	3 13 2
800 000	Stk.	June 10	5	Continental Union, Ltd.	95–97	..	5 3 1
200,000	..	..	7	Do. 7 p.c. Pref.	135–137	..	5 2 2
492,270	Stk.	—	5½	Derby Con. Stk. . . .	122–124	..	4 8 9
55,000	..	—	4	Do. Deb. Stk. . . .	104–105	..	3 16 2
148,995	..	Apl. 1	5	East Hull 5 p.c. Ord. .	96–98	..	5 2 0
486,090	10	July 14	12	European, Ltd. . . .	23¼–24	..	5 0 0
354,060	10	..	12	Do. £7 10s. paid.	17⅞–18½	..	4 18 8
16,179,445	Stk.	Aug. 12	4⅜	Gas 4 p.c. Ord. . .	105–106	..	4 8 0
2,600,000	..	..	3½	light and 3½ p.c. max. . .	87–89	..	3 18 8
4,002,235	..	..	4	4 p.c. Con. Pref.	102–104	..	3 16 11
4,531,705	..	June 29	3	Coke 3 p.c. Con. Deb.	80–82	..	3 13 2
258,740	Stk.	Mar. 16	5	Hastings & St. L. 3½ p.c.	94–96	..	5 4 2
82,500	..	..	6½	Do. do. 5 p.c.	117–119	..	5 9 3
70,000	10	Apl. 29	11	Hongkong & China, Ltd.	17–17½	..	6 5 9
131,020	Stk.	Mar. 16	7½†	Ilford A and C . . .	147–150	..	4 18 4
65,780	..	..	5½†	Do. B	114–116	..	5 1 3
65,500	..	June 29	4	Do. 4 p.c. Deb. . . .	98–100	..	4 0 0

Issue.	Share.	When Dividend.	Dividend or Dividend & Bonus.	NAME.	Closing Prices.	Rise or Fall in Wk.	Yield upon Investment.
£			p.c.				£ s. d.
4,940,000	Stk.	May 12	9†	Imperial Continental .	184–186	..	4 16 9
1,235,000	Stk.	Aug 12	3½	Do. 3½ p.c. Deb. Red.	92–94	..	3 14 5
200,242	Stk.	Aug. 31	6	Lea Bridge Ord. 5 p.c. .	119–121*	..	4 19 2
561,000	Stk.	..	10	Liverpool United A. .	214–216*	..	4 12 7
718,100	..	..	7	Do. B . .	161½–163½*	..	4 5 8
306,083	..	June 29	4	Do. Deb. Stk.	104–106	..	3 15 6
75,000	5	June 29	6	Malta & Mediterranean.	4 1/16–4 3/16	..	6 4 8
560,000	100	Apl. 1	5	Met. of 5 p.c. Deb.	100–102	..	4 18 0
250,000	100	..	4½	Melbourne 4½ p.c. Deb.	100–102	..	4 8 3
541,920	20	May 27	3½	Monte Video, Ltd. . .	12⅝–13	..	5 7 8
1,775,892	Stk.	July 28	4⅜	Newc'tle & G'tesh'd Con	101⅛–102⅛	+⅛	4 5 4
529,435	Stk.	June 29	3½	Do. 3½ p.c. Deb.	90–91	..	3 16 11
55,940	10	Aug. 31	7	North Middlesex 7 p.c.	13–13⅛*	..	5 3 8
300,000	Stk.	Apl. 29	8	Oriental, Ltd. . . .	138–140	..	5 14 4
60,000	5	Apl. 1	8	Ottoman, Ltd. . . .	6¼–6½	..	6 3 1
31,800	53	Aug. 31	13	Portsea Island A. . .	131–133*	..	5 3 0
60,000	50	..	13	Do. B. . . .	124–126*	..	5 3 2
100,000	50	..	12	Do. C. . . .	117–119*	..	5 0 10
114,800	50	..	10	Do. D and E.	99–101*	..	4 19 0
398,490	5	Apl. 29	7	Primitiva Ord. . . .	7⅛–7⅜	+1/16	4 13 4
796,980	5	June 29	5	Do. 5 p.c. Pref. .	5⅛–5⅜	..	4 13 0
488,900	100	June 1	4	Do. 4 p.c. Deb. .	97–99	..	4 0 10
312,650	Stk.	June 29	4	River Plate 4 p.c. Deb. .	97–99	..	4 0 10
250,000	10	Apl. 1	9	San Paulo, Ltd. . . .	15⅞–16⅛	..	5 10 9
62,500	10	..	6	Do. 6 p.c. Pref. .	11⅞–12⅛	..	4 18 0
125,000	50	July 1	5	Do. 5 p.c. Deb. .	51–52	..	4 16 2
135,000	Stk.	Mar. 16	10	Sheffield A	234–236	..	4 4 9
209,984	..	..	10	Do. B	234–236	..	4 4 9
523,500	..	..	10	Do. C	234–236	..	4 4 9
70,000	10	May 27	7	South African	11–11¼	..	6 1 9
6,429,895	Stk.	Aug. 12	5/9/4	South Met., 4 p.c. Ord.	120–122	..	4 9 7
1,895,445	..	July 14	8	Do. 3 p.c. Deb.	79–81	..	3 14 1
209,820	Stk.	Aug. 31	8	South Shields Con. Stk.	153–154*	..	5 3 11
605,000	Stk.	Aug. 12	5⅜	S'th Suburb'n Ord. 5 p.c.	120–122	..	4 12 9
60,000	..	..	5	Do. 5 p.c. Pref. .	120–122	..	4 2 0
117,058	..	July 14	5	Do. 5 p.c. Deb. Stk.	121–123	..	4 1 4
502,310	Stk.	May 12	5	Southampton Ord. . .	110–112	..	4 9 3
120,000	Stk.	Aug. 12	7	Tottenham A 5 p.c. .	136–138	..	5 1 5
483,940	..	..	5⅜	and B 3½ p.c. .	111–113	..	4 17 4
149,470	..	June 29	4	Edmonton 4 p.c. Deb.	97–99	..	4 0 10
182,380	10	June 10	8	Tuscan, Ltd.	9–9½	..	8 8 6
149,900	10	July 1	5	Do. 5 p.c. Deb. Red.	97–99	..	5 1 0
236,476	Stk.	Aug. 31	5	Tynemouth, 5 p c max.	111–113*	+½	4 8 6
255,636	Stk.	Aug. 31	6¾	Wands- B 3½ p.c. . .	136–138*	+⅛	4 17 10
85,766	..	June 29	3	worth 3 p.c. Deb. Stk.	73–75	..	4 0 0

Prices marked * are "Ex div." † Next dividend will be at this rate.

Natural Gas: From Sussex to China.

Under this heading, the following remarks appeared in the "Chat on 'Change" in the "Daily Mail" yesterday. "When the further attempt at financing the South of England natural gas enterprise of Heathfield, Sussex, was made some months ago, we had some criticisms to offer. Apparently by no means all the shares were placed by the Company, and the result is now one of the most curious circulars ever issued to a body of shareholders. It emanates, not from the Directors, but from the Asiatic Protection Society of Great Britain and China, Bank Chambers, 14, Shepherd's Bush Green! It explains that negotiations are proceeding between the Society and the South of England Natural Gas and Petroleum Company, Limited, 'for the purpose of introducing the various governors and officials of the districts of China to the South of England Natural Gas Company, and inducing them to accept this Company as the principal exploration company for the purpose of exploring and developing the natural gas resources in China.' According to this remarkable circular, the shareholders must understand clearly that it is not sent out 'as an inducement by us for you to obtain more shares.' Several foreign banks have been approached in the matter of taking up the shares; and the Asiatic Protection Society thinks it only fair that the shareholders of the South of England Natural Gas Company should have the first refusal of the balance. It does not definitely say whether the several foreign banks have refused or not. 'When the Company have obtained the necessary capital and have sunk their 2000-feet shaft, there will be a great surprise, which we are perfectly certain will drive the shares to a high premium; and it would then be a pity for the Continental holders to reap the benefit.' It is scarcely necessary to quote more from the amusing circular. It seems to us to make it clear that, far from subscribing for any more shares, the shareholders had better take the opportunity of getting rid of those they have to the 'several foreign banks'—that is, if any such opportunity is presented."

Inclined Retorts at Wolverhampton.—At the recent half-yearly meeting of the Wolverhampton Gas Company, the Chairman (Mr. B. Orlando Clark), in moving the adoption of the report, which showed a net profit of £10,406, remarked that it was slightly better than last year—a condition of things they all hoped would continue. The balance carried forward was better than the previous one; and he was able to assure the shareholders that the works (under the supervision of Mr. P. G. Winstanley, the Manager) had been kept thoroughly in order. The new sloping retorts were working more satisfactorily than ever; and it was worth mention that every time they replaced them—whether or not it was because the men got to understand the building of them better he could not say—they made more gas with the same quantity of coal. The report was adopted; and it was agreed to declare dividends at the rates of 3 per cent. on the preference stock, £5 2s. 6d. per cent. on the consolidated stock, and £3 2s. 6d. per cent. on the new ordinary stock, less income-tax.

The Supply of Gas to Derbyshire Villages.—The Company recently formed to acquire the gas-works at Chapel-en-le-Frith from the owner, and to put down new works for the supply of gas to Chinley, Bugsworth, and district, will pay £12,500 for the existing undertaking at Chapel-en-le-Frith. There is also an agreement to the effect that the Company shall sell their undertaking to the District Council, should that body at some future time decide to purchase the same. It is proposed by the Company to construct new works at Bugsworth, and to ultimately extend the gas supply to Dove Holes.

Ottoman Gas Company, Limited.—At the meeting of this Company next Tuesday, the Directors will report that the gas-rental for the six months ended the 30th of June amounted to £18,607, compared with £17,082 for the first half of 1909. The net profit is £4205, against £4203. The amount standing at the credit of the profit and loss account is £11,971; and the Directors recommend the payment of a dividend at the rate of 7 per cent. per annum on the preference shares, less income-tax, and at the rate of 8 per cent. per annum on the ordinary shares, tax free, leaving a balance of £9076 to be carried forward.

Bodmin Gas Company.—The annual general meeting of this Company was held on the 26th ult.—Mr. H. D. Foster in the chair. In moving the adoption of the Directors' report, he said the financial position of the Company was much more satisfactory now than it was this time last year. The policy of the Board had been to bring the works up to date, and in this they had had the excellent assistance of the Manager (Mr. R. Greenaway), to whom they were indebted. Having dealt with various items in the balance-sheet, the Chairman referred to the fact that the quantity of gas unaccounted for was now only 8·17 per cent.; whereas it had been as high as 13 per cent. and upwards. The report was adopted; and dividends of 7s. 4d. per share on the ordinary shares and 1s. 7d. per share on the "B" shares—equal to 8 per cent., the same as last year—were declared.

Improvements at the Camborne Gas-Works.—Speaking at the annual meeting of the Camborne Gas Company on the effect of the improvements carried out at the works, Mr. S. J. Ingram, of Truro, the Consulting Engineer to the Company, said they had had an increase in every direction. Notwithstanding competition by other illuminants, the sale of gas last year was no less than 3 million cubic feet in excess of that of the previous twelve months. Several large consumers had been added, and no fewer than 300 small ones. The output of coke increased by upwards of 1000 tons; and there was additional profit from the sulphate of ammonia plant. On the other hand, there had been an increase in the expenditure on repairs. This money had been wisely and judiciously laid out. They had commenced a systematic overhauling of the meters—a very necessary thing, for 95 per cent. of those which were defective were registering against the Company. Mr. C. Bryant, one of the Directors, remarked that the whole of the improvements had been carried out without a single charge by the contractors for extras. This was remarkable evidence of the care with which the plans and specifications were drawn up.

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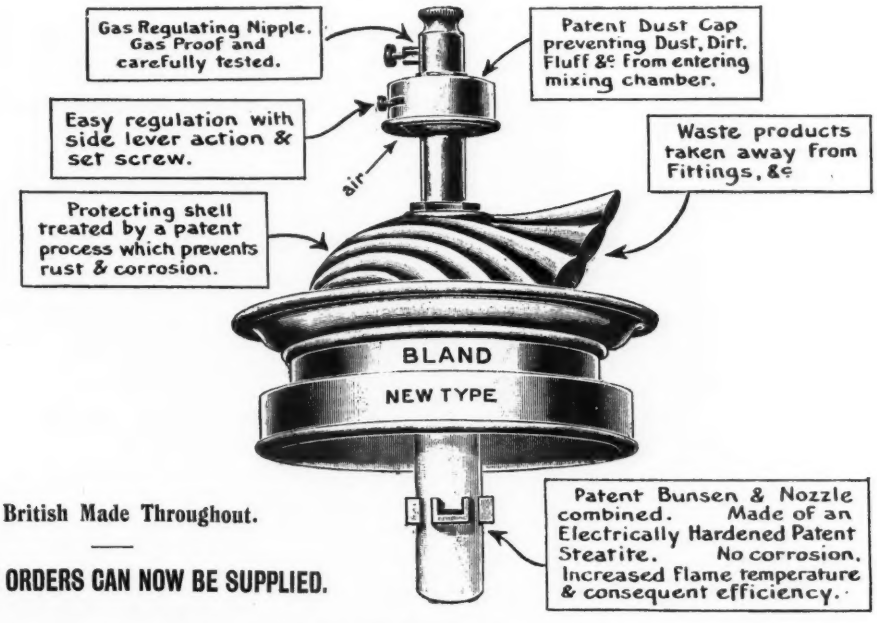
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Harrow and Stanmore Gas Company.—At the half-yearly meeting of this Company yesterday, the Directors reported the continued progress of the undertaking. The balance on the profit and loss account was £10,677; and the Directors recommended dividends for the six months ended the 30th of June at the rates of £10 10s., £7 7s., and £7 per cent. per annum on the three classes of capital and guaranteed shares, all less income-tax, and the addition of £458 to the reserve fund. This will leave £4885 to be carried forward.

Gas in Iceland.—According to a paragraph in the "Daily Mail," at a recent meeting of the Town Council of Reykjavik, the capital of Iceland, half of the members of which are women (the Mayor having the casting vote), the question under consideration was whether the town should be lighted by gas or by electricity. The women voted unanimously for gas, in order that they might utilize it in cooking-stoves. The men went solid for electricity. The Mayor was in a dilemma; but he finally gave his vote for the women. It is stated that arrangements are now being made for the manufacture of gas.

Elsecar, Wentworth, and Hoyland Gas Company.—At the annual general meeting of this Company on Wednesday week, the Directors reported that the quantity of gas manufactured during the year ended the 30th of June showed a decrease of 723,800 cubic feet; while the sale was down by 559,500 cubic feet. There was a decrease of 1,751,900 cubic feet through ordinary meters; but prepayment meters showed an increase of 1,169,200 cubic feet, and the public lamps one of 26,200 cubic feet. The amount of profit for the year was £1292, which, with the balance from last year, made £1213. The net profit was £2506, from which the Directors proposed to pay a dividend of 10 per cent. per annum, less income-tax, and carry the balance forward. During the year, the Hoyland Nether Urban District Council approached the Company, and made terms for the sale of their undertaking; but when the Council appealed to the ratepayers for permission to promote a Bill, it was refused by an overwhelming majority. The Council afterwards let the matter drop.

Southend Gas Company.—At the half-yearly meeting of this Company last Tuesday, the Directors reported that the balance on the profit and loss account for the six months ended the 30th of June was £10,227; and they recommended the payment of dividends at the rate of 5¾ per cent. per annum on the original consolidated and new ordinary stocks, and of 5⅞ per cent. per annum on the new ordinary "B" stock (less income-tax), amounting together to £7303, and leaving £2924 to be carried forward. The increased sale of gas during the half year, as compared with the corresponding period of 1909, was 3,841,100 cubic feet, or equal to 2·43 per cent. The number of consumers increased by 649; there being now 12,705, of which 9088 are on the prepayment system. A reduction of 2d. per 1000 cubic feet in the price of gas was made from Lady Day last. The report of the Engineer and Manager (Mr. F. Clark) for the half year was to the effect that the plant was in efficient condition. Additions and improvements had been effected, and were in course of progress, which would reduce the cost of working. The report was adopted.

Rugby Gas Company.—The half-yearly meeting of this Company was held last Wednesday—Mr. A. J. Lawrence presiding. In their report, the Directors stated that the receipts on revenue account for the six months ended June 30 amounted to £12,131, and the expenditure to £8291; leaving £3840 to be carried to the profit and loss account. The net balance was £13,958; and the Directors recommended a dividend for the half year on the original share capital at the rate of 14½ per cent. per annum (less income-tax), amounting to £2560; and likewise a dividend on the additional capital at the rate of 11½ per cent. per annum, which would amount to £303. The report was adopted.

Bishop's Stortford and District Gas Company.—At the ordinary general meeting of this Company last month, the Directors reported that, compared with the six months ended the 30th of June, 1909, there was an increase of 690,400 cubic feet, or 2·9 per cent., in the sale of gas in the past half year; and that the sale of residuals had brought a better return. There was a disposable balance of £2041; and the Directors recommended the payment of dividends at the rates of 4 and 5 per cent. per annum on the preference stocks, and of £7 15s. and £7 10s. 6d. per cent. per annum on the original and additional ordinary stocks, less income-tax. These dividends required £1224, and left a balance of £817 to be carried forward. The Directors expressed their pleasure in reporting that the Bishop's Stortford, Harlow, and Epping Gas and Electricity Bill had received the Royal Assent. By the provisions of the Act, the amalgamation of the undertakings belonging to the Bishop's Stortford, Harlow and Sawbridgeworth, Epping and Ongar Gas Companies, and the purchase of those belonging to the Newport and Much Hadham Gas Companies, will take effect on and from Jan. 1, 1911.

The Water Question in the Rhymney Valley.—At a recent private meeting of the Gelligaer Urban District Council, it was decided to join the Caerphilly District Council in promoting a Bill next session for the purchase of the undertaking of the Rhymney and Aber Valleys Gas and Water Company, to which reference was made last week (p. 598). Mr. Raikes (Messrs. Wilcox and Raikes, of Birmingham) was present. It transpired that, in accordance with a report made by him to a previous joint conference of the authorities in the Rhymney Valley, efforts should be made to get a sufficient water supply for Caerphilly and the lower portions of Gelligaer from the Merthyr Corporation, who own the Taf Fychan source, which is regarded as the finest in South Wales. There is a surplus supply here to meet the demands of three times the present population of Merthyr and afterwards satisfy the needs of the inhabitants of the valley. It was reported at the meeting that a joint conference between the deputation from the valley and the members of the Corporation had been held the previous day; but that Merthyr put on a prohibitive charge for the surplus water. The members of the Gelligaer Council strongly denounced this dog-in-the-manger policy, and decided that, in the event of Merthyr not coming to a more amicable arrangement, a new and independent source of supply should be tapped near the Brecon Beacons.

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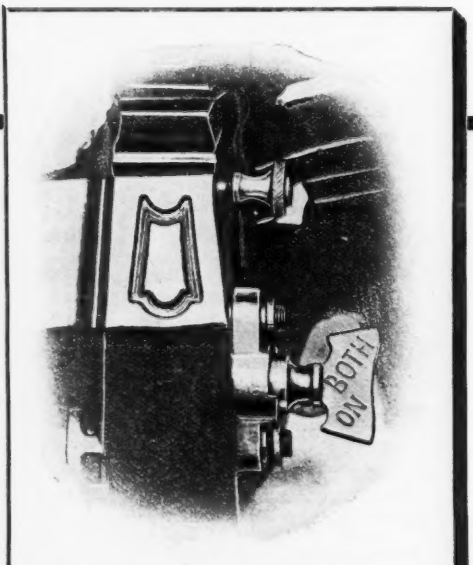

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Woking Water and Gas Company.—At the meeting of the Company yesterday, the Directors reported that the balance at the credit of the profit and loss account for the six months ended the 30th of June was £5326, out of which they recommended the payment of a dividend at the rate of 5 per cent. per annum (less income-tax) for the half year. This would absorb £3961, and leave £1365 to be carried forward. During the six months, 84 additional house and 15 meter connections were made; and the mains were extended by about 3305 yards.

The Fire at the Brussels Exhibition.—In view of what has been said in the "JOURNAL" on this subject, we give, under reserve, a statement which appeared in the papers last week, to the effect that the Electric Supply Publicity Committee, of Moorgate Court, E.C., have had the personal assurance of the Engineer and Director of the Electrical Department of the City of Brussels, that the fire was not caused electrically, and, further, that the supply of electricity had been cut off in the buildings where the trouble started some hours prior to the commencement of the fire.

Watford Gas Company.—At the recent half-yearly meeting of this Company, the Chairman (Mr. E. J. Slinn), in moving the adoption of the Directors' report, referred to the low cost of producing gas (£450 per million cubic feet), and to the increased make per ton of coal compared with ten years ago. It was then 10,400 cubic feet, whereas now it was 12,500 feet. The sale of gas had realized £500 less than before; but as the price had been reduced 2d. per 1000 feet since the previous meeting, the Company were actually £400 better off. This showed that their customers always responded well to a decrease in price. The co-partnership scheme had been very successful; practically the whole of the staff having gone in for it. The report showed a profit of £4101 on the revenue account, and a balance of £6284 available for distribution; and the Chairman proposed that dividends of 7¼ and 5¾ per cent. be declared for the past half year. This was agreed to.

Leigh-on-Sea Gas Finances.—At the meeting of the Leigh-on-Sea Urban District Council last Wednesday, the Gas Committee reported that they had considered the statement of the amount overspent on the gas capital account—viz., £2442—and suggested that the Finance Committee should be asked to recommend that application be made to the Local Government Board to sanction the borrowing of £1442 to repay part of the total, and that the remaining £1000 be debited to the gas revenue account. The Finance Committee, however, were of opinion that, inasmuch as the proposed course would be at variance with the previous decision of the Council, they could not properly recommend its acceptance. The Gas Committee added that they had considered the question of the sums which would be likely to be required for works chargeable to capital and new stock during the ensuing twelve months, and had resolved to ask the Finance Committee to recommend that application be made to the Local Government Board for sanction to a loan of £3881. The Finance Committee approved this proposal. A long discussion took place on the matter; but in the end the recommendation was approved—some of the items, however, being increased to allow for contingencies.

Suicide by Gas.—At an inquest at St. Pancras on the body of James Gilby, a carman, who died of coal-gas poisoning, a daughter stated that deceased worried through losing his work. She found him on the floor of his room with an overcoat over his head, and under this a pillow-case, in which was a gas-ring. The tap was turned full on.

Cost of Water Diviners.—The Chairman and several members of the Redcar Urban Council recently received notice to meet the official auditor with reference to certain items of expenditure which it is understood may be surcharged against those who signed cheques. Some of the items relate to the engagement of a water diviner to advise the Water Committee as to new sources of supply for the parish.

Bideford Water Supply.—It was decided by the Bideford Town Council at their last meeting to apply to the Local Government Board for permission to borrow £2000 for the purpose of relaying the water-mains. It was urged by some of the councillors that the provision of a more adequate supply of water was of great importance. The Mayor (Mr. J. Heywood) said the relaying of the mains was necessary, apart from the question of the improvement of the supply, and to defer it would be a great blunder. A long time would elapse before a new supply could be obtained and brought into use; but the mains could be relaid as opportunity served, and the work spread over a longer or shorter period.

Bolton's Increased Water Charges.—The proposal of the Bolton Corporation to increase the charge for water for trade purposes from 6d. to 9d. per 1000 gallons to Bolton consumers, and from 9d. to 1s. 1½d. to out-district consumers, is being opposed by the authorities in the several districts included in the supply area of the Corporation. At a conference of representatives of the out-districts, a deputation was appointed to wait upon the Water Committee, to protest against the proposed increase in the charges; and Counsel's opinion is to be obtained as to the legality of the Corporation charging consumers in the borough only 6d. per 1000 gallons, whereas the cost to themselves was 6½d.—the deficiency being made up by the extra charge to consumers outside the borough.

Hartlepool Gas and Water Supply.—At the annual meeting of the Hartlepool Gas and Water Company last Tuesday, the report of the Directors showed that the total receipts on revenue account for the year were £86,346, and the expenses £50,481; leaving a balance of £35,865 to the credit of the profit and loss account. Of this sum, £3339 had been paid for interest on loans, and £15,822 as interim dividend. The Directors recommended that out of the balance of £16,704 the sum of £750 should be appropriated to meet the cost of the renewal of water-mains, and a dividend paid for the past half year at the rate of 5 per cent. per annum, less income-tax. The Directors reported that the trade of the district, while showing some slight improvement, was still far from satisfactory. It was gratifying, however, to note that through the local iron-works being fully employed, there had been an increase in the consumption of water. The reservoirs and wells continued to yield a supply much in excess of present requirements. The report was adopted.

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Effect of the Tarring of Roads.—The "Estates Gazette" says: "We never remember to have seen the highways of England in such comparatively splendid condition as they have been during the summer that is nearing its close. The tarring of roads must be given credit for a very great deal of the vastly improved condition of things."

Leakage of a Reservoir Caused by Moles.—Considerable trouble has been caused at Totnes by the leaking of the Bowden reservoir. The Water Committee of the Corporation recently visited the place and had the ground opened, with the result that they came to the conclusion that the leakage was caused by moles burrowing in the bank. It was decided that a sheet of iron of thick gauge should be put in on each of the clay dams, and be well puddled with clay. By this means it is hoped to exclude the moles and prevent the leakage, which has been going on for some years.

New Joint Stock Companies Registered.—The Chapel-en-le-Frith, Chinley, and District Gas Company, Limited, has been registered with a capital of £20,000, in £1 shares, to acquire from Mr. W. Walker, of Gomersal, the undertaking known as Chapel-en-le-Frith Gas-Works, Derby, including the benefit of the Chapel-en-le-Frith Gas Order, 1876. The United Lighting Maintenance Company, Limited, has been registered with a capital of £2000, in £1 shares, to take over the business of electricans, &c., carried on by S. Mundler at No. 35, Cock Lane, E.C., as the National Lighting Company.

Another Lamplighting Device.—According to an article in the "South Wales Echo" for the 29th ult., two Cardiff watchmakers have patented a device for lighting incandescent street-lamps simultaneously by touching an electric button. It is claimed by the inventors that all the street-lamps in the borough, or in any particular area, can be lighted or extinguished simultaneously by their invention, which can also regulate the quantity of gas admitted to the burner. The proposal involves, of course, the connection of all the gas-lamps by electric wires with the central station. It is stated that a small apparatus placed in every lamp will, when the current is sent through by pressing a button at the central station, turn on the gas and create a spark just sufficient to ignite it.

Wallasey Water Supply.—The Wallasey Urban District Council, whose area comprises the rapidly developing places of New Brighton, Liscard, Egremont, Seacombe, and Wallasey, have recently received a Charter of Incorporation. Up to eight years ago, the district derived its water supply from deep wells sunk on the confines of the district. But the phenomenal growth of all the townships caused them to apply to the Liverpool Corporation for a supply of water from their Vyrnwy system; and a pipe-line, 30 miles in length, was laid from the Vyrnwy aqueduct, where it passes through Delamere Forest, to the Wallasey boundary at Leasowe. The Wallasey Council have been taking, up to the present, 500,000 gallons of water daily; but the Water Committee have passed a resolution asking for an increase to 750,000 gallons. The agreement between the Liverpool Corporation and Council provides for an ultimate delivery of 2 million gallons per day.

City of Chichester Gas Company.—At the half-yearly general meeting of this Company last Tuesday, the accounts presented showed a balance of £1961 standing to the credit of the profit and loss account, out of which the Directors recommended dividends at the rates of £8 and £5 12s. per cent. per annum, less income-tax. They expressed regret that the Chichester Corporation had given notice to determine the existing contract (dated Dec. 10, 1909) for lighting the public lamps of the city, at the end of the first year of the term of five years therein mentioned. The Engineer (Mr. T. Ebenezer Pye, F.C.S.) reported that the works and mains were in good repair and condition. The Chairman (Mr. Alfred Lass), in moving the adoption of the report, referred at great length to the action of the Corporation in accepting the tender of the Electric Light Company; but, in reply to a question, he said that, in consequence of the low price at which the Company had supplied gas for public lighting, the termination of the contract would have very little effect upon the profits. The report was adopted.

The Directors of the Antwerp Water-Works Company, Limited, announce their intention to pay an interim dividend of 5½ per cent. for the half year ended the 30th of June.

At a meeting of the Water Committee of the Manchester Corporation last Thursday, it was reported that, estimating the average daily consumption of water at 42,000,000 gallons, there was in stock a supply equal to 128 days.

A proposal has been made by the Frimley and Farnborough Water Company to extend their service so as to connect Hook with the Eversley district. An application in connection with this suggested extension is now being considered by the Hartley Wintney Parish Council.

The bursting of a 3-inch water-main caused both consternation and inconvenience to the inhabitants of the Stoke Road district, Slough, on Wednesday last. The discovery was made owing to a subsidence in the centre of the roadway; and when an examination took place, it was found that one length of pipe had snapped off owing to the loosening of the earth below and the giving way of planks which were put in some time ago when the sewer was laid underneath the water-main. In some places, there was a dropping of the surface to the extent of 2 feet.

Early on the morning of the 23rd ult., a fire occurred in the historic hostelry, the Star Hotel, at Newport (I. of W.), which destroyed the building and the Friendly Societies' Assembly Hall connected with it, and jeopardized the lives of the tenant, Mr. E. H. Walker, his young daughter, and the barmaid. The premises were left apparently safe when Mr. Walker and the others retired for the night; and there having been no fire or gas light in the part of the premises where the outbreak seemingly occurred—the private room behind the bar—it is conjectured that the electric light wires fused, and caused the fire. The electric light had become defective, and orders had been given for the overhaul of the installation.

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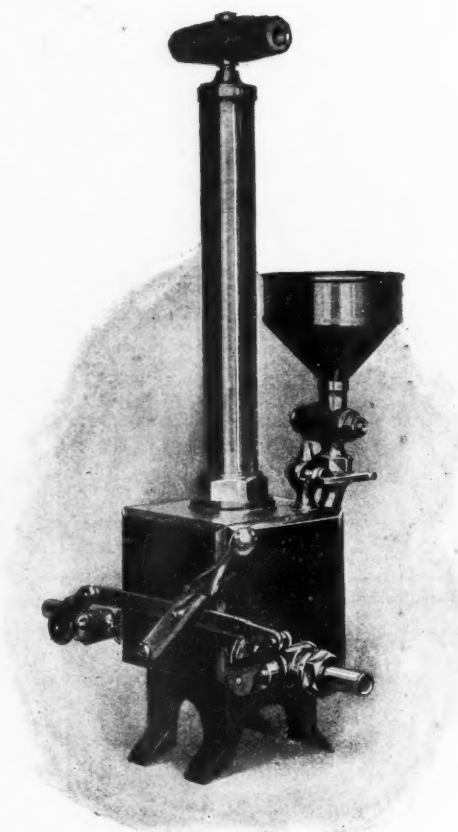

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Meetings.

BRITISH GASLIGHT COMPANY. Offices. Sept. 21, Twelve o'clock.
OTTOMAN GAS COMPANY. Offices. Sept. 13, One o'clock.

Patent Licenses, &c.

"MANUFACTURE OF BURNERS FOR HIGH-PRESSURE LIGHTING AND HEATING PURPOSES." Marks and Clerk, Lincoln's Inn Fields, W.C.

Plant, &c., for Disposal.

FILTER PRESS. Sutton (Surrey) Gas Company.
STREET GAS-LAMPS. Carmarthen Town Council. Tenders by Oct. 15.

TENDERS FOR

Coke.

WANDSWORTH AND PUTNEY GAS COMPANY. Tenders by Sept. 16.

Exhausters.

DEVONPORT CORPORATION. Tenders by Sept. 10.

General Stores (Birch Brooms, Brass Couplers and Stop Cocks, Limestone, Cast Iron Retort Mountings, Malleable and Cast Steel Castings, &c.).

GLASGOW GAS DEPARTMENT. Tenders by Sept. 27.

Gas Cookers and Heating Stoves.

BELFAST GAS DEPARTMENT. Tenders by Sept. 16.

Meters (Ordinary and Prepayment).

BELFAST GAS DEPARTMENT. Tenders by Sept. 16.

Pipes, Castings, &c.

GLASGOW GAS DEPARTMENT. Tenders by Sept. 27.

NOTICES TO CORRESPONDENTS, ADVERTISERS, AND SUBSCRIBERS.

No notice can be taken of anonymous communications. Whatever is intended for insertion in the "JOURNAL" must be authenticated by the name and address of the writer; not necessarily for publication, but as a proof of good faith.

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Friedrich Lux, Ludwigshafen-am-Rhein.

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The next Session begins on Oct. 4, 1910, on which day the Entrance Examination will be held at Ten a.m. and Two p.m.
W. F. Husband, Registrar.

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THE Carmarthen Town Council have
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Tenders, marked "Tenders for Lamp Posts, &c.," to be sent to the undersigned not later than the 15th of October, 1910.
The highest or any Tender not necessarily accepted.
James John, Town Clerk.
Town Clerk's Office, Carmarthen, Aug. 18, 1910.

COUNTY BOROUGH OF DEVONPORT.
(Gas Department.)
TENDERS are invited for the Supply
and Erection of Two 60,000 Cubic Feet EXHAUSTERS.
Further Particulars may be obtained from the undersigned.
Tenders, endorsed "Exhausters," addressed to the Town Clerk, Devonport, must be delivered on or before Sept. 10, 1910.
W. P. Tervet, Engineer and Manager.

OFFERS wanted for the Files of the "JOURNAL OF GAS LIGHTING," "GAS WORLD," and "CHEMICAL TRADE JOURNAL," for the Years 1905 to 1909, inclusive, unbound.

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(GAS DEPARTMENT.)

TENDERS are invited for the Supply of DRY METERS (Ordinary and Prepayment), also GAS COOKERS, HEATING STOVES, &c., for One Year from the 1st of October, 1910.

Conditions and Forms of Tender may be had on Application to the Engineer and Manager at the Gas-Works.

Tenders, endorsed "Tender for Meters," or "Tender for Gas Appliances," will be received by the undersigned not later than Twelve o'clock, on the 16th of September, 1910.

The lowest or any Tender not necessarily accepted.

R. MEYER,
Town Clerk.

COKE.

THE Directors of the Wandsworth and Putney Gaslight and Coke Company invite TENDERS for the Removal of about 15,000 Tons of Guaranteed "WANDSWORTH" COKE from their Works at Wandsworth, between Oct. 1 next and March 31, 1911.

The Coke to be removed by Van or by Barge (free waterway on River Thames).

Sealed Tenders, endorsed "Tender for Coke," to be delivered not later than Sept. 16.

The Directors reserve to themselves the right to accept any Tender in part or in whole, and do not bind themselves to accept the highest or any Tender.

Any further Information may be obtained from the Engineer, Mr. H. O. Carr.

CHAS. W. BRAINE,
Secretary.

Wandsworth and Putney Gaslight and Coke Company, Fairfield Street, Wandsworth, S.W.

CORPORATION OF GLASGOW.
(GAS DEPARTMENT.)

THE Corporation invite Tenders for Supplying the following MATERIALS, as may be required by the Gas Department, for Twelve Months from date of acceptance—viz:

1. Birch Brooms.
2. Brass Couplers and Stop Cocks.
3. Cast-Iron Pipes and Special Castings.
4. Cast-Iron Retort Mountings and other Castings.
5. Cast-Iron Screwed Saddles, and Double Faucet Stop Cocks.
6. Corks and Bungs.
7. Gas Hot-Plates for Kitchen Ranges.
8. Gun-Metal, &c., Castings.
9. Hay.
10. Limestone.
11. Malleable Iron Tube and Fittings.
12. Malleable and Cast Steel Castings, Bogie Wheels, and Rake Heads.
13. Meter Boards and Wood Rhones.
14. Tin Pans and Grids.

Also TENDERS for:—

1. Cartage of Ashes, &c., at Provan and Tradeston Gas-Works.
2. Cartage for Street Mains and Workshops Departments.

Specifications and Forms of Tender may be obtained, and Samples examined, on Application to Mr. Alex. Wilson, Gas Engineer, 45, John Street, Glasgow.

Sealed Tenders, marked outside "Gas Department, Tender for ——," must be lodged with the Subscriber, on or before Tuesday, the 27th of September current.

The lowest or any Tender may not necessarily be accepted.

A. W. MYLES,
Town Clerk.

City Chambers, Glasgow,
Sept. 3, 1910.

BRITISH GASLIGHT COMPANY, LIMITED.

NOTICE is Hereby Given, that the HALF-YEARLY ORDINARY GENERAL MEETING of the Proprietors of this Company will be held at this Office on Wednesday, the 21st inst., at Twelve o'clock precisely, to transact the usual Business; to declare a Dividend for the Half Year ended the 30th of June last; to elect Two Directors in the place of those who go out by rotation; and to appoint Two Auditors.

NOTICE IS HEREBY ALSO GIVEN that the TRANSFER BOOKS of the Company WILL BE CLOSED on the 10th inst. and RE-OPENED on the 22nd inst.

By order of the Court of Directors,
A. W. BROOKES,
Secretary.

Chief Office: No. 11, George Yard, Lombard Street, London, E.C.
Sept. 2, 1910.

OTTOMAN GAS COMPANY, LIMITED.

NOTICE is Hereby Given, that the ORDINARY GENERAL MEETING of the Shareholders of this Company will be held at 9, Queen Street Place, Cannon Street, E.C., on Tuesday, Sept. 13, 1910, at One o'clock precisely, to receive the Report of the Directors, and Statement of Accounts for the Half Year ended the 30th of June last; to declare a Dividend; and for General Purposes.

The TRANSFER BOOKS WILL BE CLOSED from Sept. 6, to Sept. 13, both days inclusive.

By order of the Board,
THOMAS GUYATT,
Secretary.

9, Queen Street Place,
Cannon Street, London, E.C.,
Aug. 30, 1910.

SALES BY AUCTION OF GAS AND WATER STOCKS AND SHARES.

MESSRS. A. & W. RICHARDS beg to notify that their SALES BY AUCTION of NEW CAPITAL ISSUED UNDER PARLIAMENTARY POWERS, and of STOCKS and SHARES belonging to EXECUTORS and other PRIVATE OWNERS in LONDON, SUBURBAN, and PROVINCIAL GAS and WATER COMPANIES, take place PERIODICALLY at the Mart, TOKENHOUSE YARD, E.C.

Terms for Issuing New Capital, and also for including other Gas and Water Stocks and Shares in these Periodical Sales, will be forwarded on Application to MESSRS. A. & W. RICHARDS, at 18, FINSBURY CIRCUS, E.C.

THE Owners of British Patents Nos. 20,643, of 1906, entitled "IMPROVEMENTS IN AND CONNECTED WITH HIGH PRESSURE AND OTHER BUNSEN BURNERS," and 21,158, of 1906, entitled "IMPROVEMENTS IN BUNSEN BURNERS FOR ILLUMINATING AND HEATING PURPOSES," are desirous of DISPOSING of the Patents or Entering into a WORKING ARRANGEMENT, under LICENSE, with Firms likely to be interested in the same. In the alternative, the Owners would be open to consider Proposals to MANUFACTURE THE INVENTIONS, to fill any requirements of the Market in Great Britain, on Terms to be arranged. The Patents cover Inventions interesting to Gas Burner Makers, especially those suitable for High-Pressure Gas for Heating purposes. Detailed Information as to the inventions will be found in the Patent Specifications, of which copies will be supplied to any interested party on request.

Full Particulars can be obtained from, and Offers made (for transmission to the Owners) to, MARKS AND CLERK, 57 & 58, Lincoln's Inn Fields, LONDON, W.C.

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From Lamps with more than one burner, the injectors can be removed from the outside, without taking the lamps to pieces.

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VOL. CX.

OF THE

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WATER SUPPLY, &c.

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Is sent out in Skeins all ready for use.
Every Skein of equal weight and length.
The Lead Wool Joint is built up evenly all the way through.
Lead Wool requires no melting and can be used in water without risk.

Lead Wool Joints are Twice as Strong as Cast Lead Joints and cost 33⅓ per cent. less.

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Norton's Patent "Abyssinian" Tube Wells.
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STRUCTURAL IRON AND STEEL WORK.

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AS FOLLOWS:—

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WEST'S GAS IMPROVEMENT CO., LTD.,
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"SELAS" System of Lighting.

TAKE NOTE

We are the Pioneers of lighting by means of an apparatus mixing Gas with Air **BEFORE ENTERING THE SERVICE PIPES!**

Our system is the best and most economical, which is abundantly proved by the fact that several **HIGH PRESSURE LIGHTING FIRMS** are at present endeavouring to imitate the system, but to do it successfully they seem to be bound to infringe our Patent Rights. We therefore take this opportunity of putting intending purchasers on their guard, having already taken the necessary steps to protect our interests.

"SELAS" has now been in use for nearly ten years, and all improvements made during that period are fully protected by **LETTERS PATENT.**

For Catalogue, Testimonials, Estimate, and all other information, gratis, apply to

SELAS LIGHTING COMPANY, LIMITED,

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London Office: 10, FARRINGDON AVENUE, HOLBORN VIADUCT, E.C.

ALSO MAKERS OF
"REESON" RETORT HOUSE GOVERNORS
AND "KERR" STEAM TURBINES.
PHŒNIX STEAM, TAR OR LIQUOR PUMP
"COLUMN" TAR OR LIQUOR PUMP
COKE BREAKING PLANTS
HIGH PRESSURE RAISING PLANTS – A SPECIALITY
"A" TYPE EXHAUSTER SET
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GAS VALVES ALL DESCRIPTIONS
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PHŒNIX IRON WORKS,
STROUD, GLOUCESTERSHIRE.
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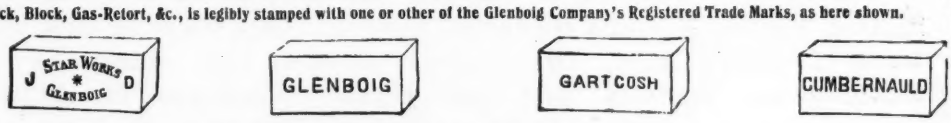
"PINKNEY" GAS & OIL ENGINES 4 TO 3 B.H.P.
AGENTS FOR SCOTLAND. D.M. NELSON & CO. GLASGOW.

THE GLENBOIG UNION FIRE-CLAY CO., LTD.

GLENBOIG FIRE-BRICKS AND GAS-RETORTS.

Every Genuine Glenboig Brick, Block, Gas-Retort, &c., is legibly stamped with one or other of the Glenboig Company's Registered Trade Marks, as here shown.

TRADE MARKS.



The Glenboig Trade Marks are imitated, and the Glenboig Name unfairly used by Makers of a lower Class of Goods, which, when sold under their own name, command much lower prices.
The Genuine Brand, Stamped on the Goods, is the only Reliable Guarantee to the Purchaser.

GAS-RETORTS, FIRE-BRICKS, BLOCKS, &c., &c.

The SPECIAL BRICKS used in the Construction of Gas Furnaces for Heating Retorts.

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Works: GLENBOIG, LANARKSHIRE.
Offices: 48, West Regent St., Glasgow.

56 Prize Medals and Diplomas of Honour.
Highest Award wherever exhibited.

The GLENBOIG BRICKS, BLOCKS, AND RETORTS combine, in the highest degree, the qualities of not melting, and not splitting, when subjected to the highest heats and most sudden changes of temperature, and are, in consequence, found to be economical, even in districts where the local bricks can be had at half the price.

Undernoted we give a Table of Analysis and Physical Characteristics of a sample of Glenboig Fire-Clay by J. T. Norman, London; and, in submitting a report from a responsible and reliable public analyst, we would here draw attention to the unreliable character of some recently published analyses where a manufacturer selects not only his own samples, but also those of his competitor, and has them treated by a private analyst. SUCH STATEMENTS ARE ALTOGETHER UNTRUSTWORTHY.

ANALYSIS OF GLENBOIG FIRE-CLAY.

By JOHN T. NORMAN, Esq., F.C.S., &c., The City Central Laboratory, LONDON.

THE GLENBOIG UNION FIRE-CLAY CO., LTD., GLENBOIG, SCOTLAND.

23, Leadenhall Street,
London, E.C., September 21st, 1909.

Dear Sirs,

I have completed the investigation of the samples of Clay received from you on the 10th inst., and now beg to report the results.

CHEMICAL ANALYSIS.

	Raw.	Fired.
Silica, free	3·03	3·49
Silica, combined	43·20	49·77
Alumina	36·55	42·10
Ferric oxide	1·80	2·08
Titanic oxide	1·30	1·50
Lime	trace	trace
Magnesia	trace	trace
Alkaline oxides	trace	trace
Sulphates as trioxides	0·92	1·06
Loss on Ignition	13·20	—
	100·00	100·00

PHYSICAL RESULTS.

Density	2·65
Volume weight	1·90
Porosity	15·4 %
Linear shrinkage at 100° C.	3·70%
" " " 1050° C.	4·76%
" " Total	8·46%
Volume shrinkage at 100° C.	10·7 %
" " " 1050° C.	12·6 %
" " Total	23·3 %
Plasticity	20·0 %
Fire Stability	1850° C. equiv. 3362° F.

(SEGER CONE 36.) (New Scale CONE 38.)

(Signed) J. T. NORMAN.

This Clay is remarkable for its high percentage of Alumina and for the almost complete absence of ingredients tending to lower the refractory properties; its fire stability is extremely high. For some years past I have been urging clients who are working the Clays of the Coal Measures to search for such a material, but you are the first to discover a supply. The possession of this Clay places you in a unique position amongst the manufacturers of refractory goods throughout the world, and I have no doubt will, if duly exploited, enable you to drive out of the market the large quantities of foreign fire-bricks which are being poured into this country for use in the construction of bye-product ovens and for other purposes.—I am, yours faithfully,

JOHN T. NORMAN.

MUNICH INCLINED CHAMBER FURNACES.

List of Munich Chamber Furnaces in Operation and under Construction:—

TOWNS.	No. of Settings.	Coal capacity per 24 hours.	No. of Chambers.
Munich, Kierchstein	5	48·5 Tons	15
Munich, Moosach (1st Order)	6	117 ,,	18
Munich ,, (2nd Order)	6	117 ,,	18
Hamburg, Grassbrook (1st Order)	10	195 ,,	30
Humburg ,, (2nd Order)	14	310 ,,	42
Berlin, Tegel	27	526 ,,	81

TOWNS.	No. of Settings.	Coal capacity per 24 hours.	No. of Chambers.
Rome	20	350 Tons	60
Paris, Genevelliers	20	272 ,,	60
Leipsiz, Connewitz	8	156 ,,	24
Hanau	8	110 ,,	24
Regensburg	5	87 ,,	15

For Particulars and Tenders apply to:

THE COKE OVENS AND BY-PRODUCTS CO., LD.,
ST. STEPHENS HOUSE, WESTMINSTER, S.W.

SPLENDID CARBONIZING RESULTS.

HIGHEST RESULTS in GAS MADE and COKE SOLD per Ton of Coal Carbonized, obtained where improved Klönne Retort Settings, constructed by us, are in operation.

Reference can be given to several Works where Regenerators are still working after a life of 10 to 15 Years.

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KLÖNNE SETTINGS A SPECIALITY. High-Class Work only.

GASHOLDER TANKS. MAINLAYING. BUILDINGS.

COAL TAR PRODUCTS.

Benzol, Toluol, Solvent Naphtha, Creosote Oils, Grease Oils, Carbolic Acid, Dark Cresylic Acid, Granulated (Crude) and Sublimed Naphthalene, Anthracene, Refined Tar and Pitch. Sulphate of Ammonia up to 20·75 per cent. Nitrogen.

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709, OLD KENT ROAD, LONDON, S.E.

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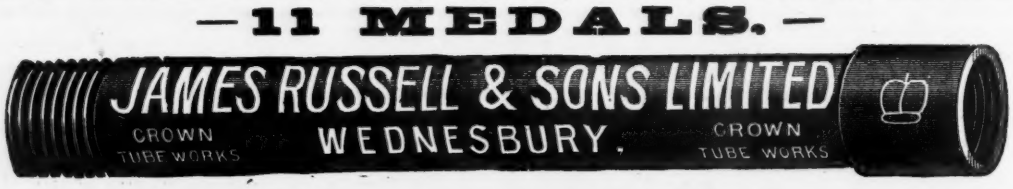

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WROUGHT-IRON OR STEEL MAINS UP TO 6 FEET DIAMETER FOR GAS, WATER, OIL, OR OTHER PURPOSES.

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LEEDS: 6, Mark Lane, New Briggate.

Welsbach LIGHT

Inverted Arc Lamp, Fig. 623.

Storm Proof—

For Exterior Lighting.

Welsbach-Kern

(Patent) Inverted System

BRITISH MADE.

BRITISH MADE.

Fig. 623. Three-Light.

Height over all.

1-light . . .	1 ft. 8 ins.
2-light . . .	2 ft. 4 ins.
3-light . . .	2 ft. 4 ins.
4-light . . .	2 ft. 7 ins.

Width over all.

1-light . . .	1 ft. 1 in.
2-light . . .	1 ft. 5 ins.
3-light . . .	1 ft. 5 ins.
4-light . . .	1 ft. 8 ins.

ENAMELLED Green Steel Casing, fitted with Welsbach-Kern Inverted Burners, Gas and Air Regulators operated from outside. Sliding Door to give access to Burners for cleaning purposes. Fitted with Magnesia Nozzles, Welsbach Mantles, and Glass Mantle Protectors. Complete as shown. Highly efficient and regenerative.

	Gas per hour.	*C.P.*	*Steel.*	*Copper Case.*
1-light	4 feet	125	**30/-**	**5/-** extra.
2-light	8 feet	260	**47/6**	**6/-** extra.
3-light	12 feet	400	**52/6**	**6/-** extra.
4-light	16 feet	550	**72/6**	**9/-** extra.

All on or off, or One light on and the rest off, **7/6** per Lamp extra. Cup and Ball, **3/6** per Lamp extra.

RENEWALS.

Glass Mantle Protectors (Fig. 623) **3/4½** per dozen, or in case lots of 5 gross, **33/-** per gross.

	1-Light.	*2-Light.*	*3-Light.*	*4-Light.*
Clear Glass Globes, each	**2/3**	**5/9**	**5/9**	**9/-**
" " " In Case lots per dozen.	**19/6**	**57/9**	**57/9**	**93/-**
Case contains . .	*80*	*18*	*18*	*12*

	1-Light.	*2-Light.*	*3-Light.*	*4-Light.*
Wired Globes, extra each	**2/-**	**2/-**	**2/9**	**3/6**
Parabolic Reflector, extra "	**3/6**	**6/-**	**7/6**	Not made

Welsbach Mantles, **4½d.** each, or **4s. 3d.** per dozen, subject as usual.

The Welsbach Mantles for Upright lighting are "C," "CX," and "Plaissetty," price **4½d.** each.

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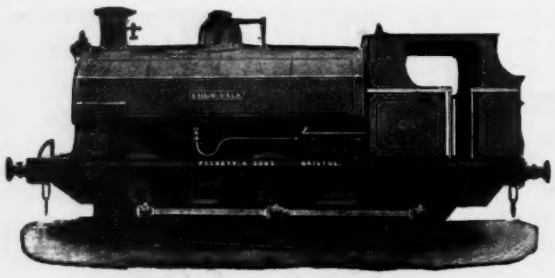
Telegrams and Cables: "WELSBACH LONDON." *Telephone 2410 NORTH.*



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Are the exclusive Owners of the well-known HAIGH HALL & KIRKLESS HALL GAS COAL COLLIERIES, Wigan, and of the Manton Steam and House Coal Collieries, Worksop, Notts, and supply the well-known Wigan Arley Mine Gas Coal, Gas Nuts, Gas Cannel, Cannel Nuts, House and Steam Coals, &c.

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Telegraphic Address: "WIGAN, BIRMINGHAM." Telephone: No. 200.

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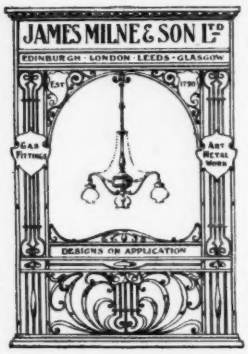
For the **LIGHTING SEASON,** 1910-1911.

INVERTED GASFITTINGS.



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THE CENTENARY PETROL GAS TURBINE GENERATOR.

NOTE—It does not matter how irregularly the number of Lights in use vary, this is the only Petrol-Air Gas Generator which maintains under all conditions of tests an unvarying quality of Gas.

TESTIMONIAL.

ROYAL SCOTTISH NURSING INSTITUTION,
69, QUEEN STREET, EDINBURGH, *24th February*, 1909.

DEAR SIRS,

I have much pleasure in testifying to the brilliance of the Lights, purity of the atmosphere of the rooms, agreeableness to the eyes, with entire absence of odour, together with the fullness of health, enjoyed by myself and inmates of St. Cyr. Ceres, during my residence for four months during Winter, while the house was lit night and morning (and small lights during night) by Petrol-Air Gas produced at the Village Gas-Works by a Centenary Turbine Gas Generator. The brilliance and comfort with the lights could not be excelled.

I am, yours truly,

(Signed) Nurse B. BROWNIE.

N.B.—St. Cyr House has 50 Burners for Lighting, besides points for Cooking and Ironing.

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NON-EXPLOSIVE and ECONOMICAL.

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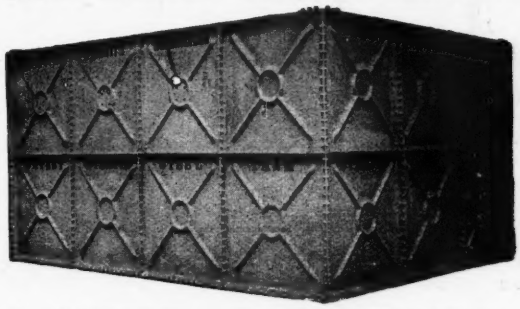
UNBREAKABLE.
EASILY ERECTED. LIGHT FOR SHIPMENT.



Capacity, 9600 Galls. *Size, 16 × 12 × 8 ft. deep.*

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MADE FROM FLANGED PLATES 4 FT. SQUARE.
ANY CAPACITY IN MULTIPLES
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WATER-GAS PLANTS.
Aggregate capacity of Plants supplied,
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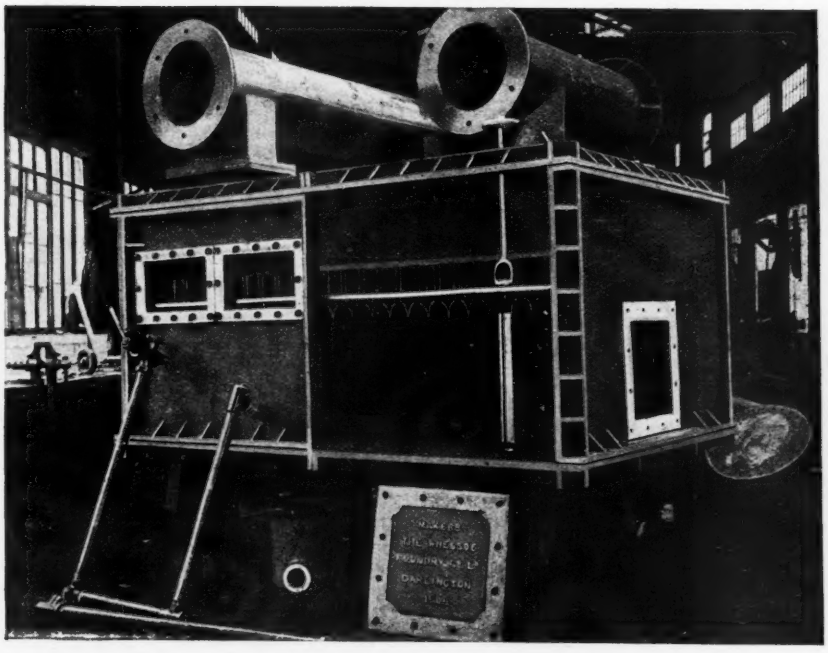

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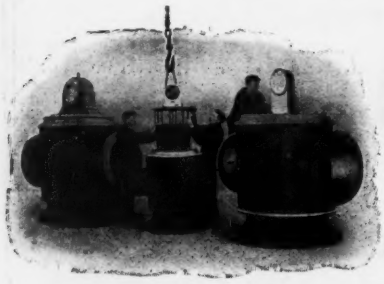
ALL their **COKE**
in their own District
At **HIGHER PRICES**
By Adopting the **COALEXLD PROCESS.**

For Particulars, apply to COALEXLD, LIMITED, LANCASTER.



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At a **Reduced Cost** of Installation, by using

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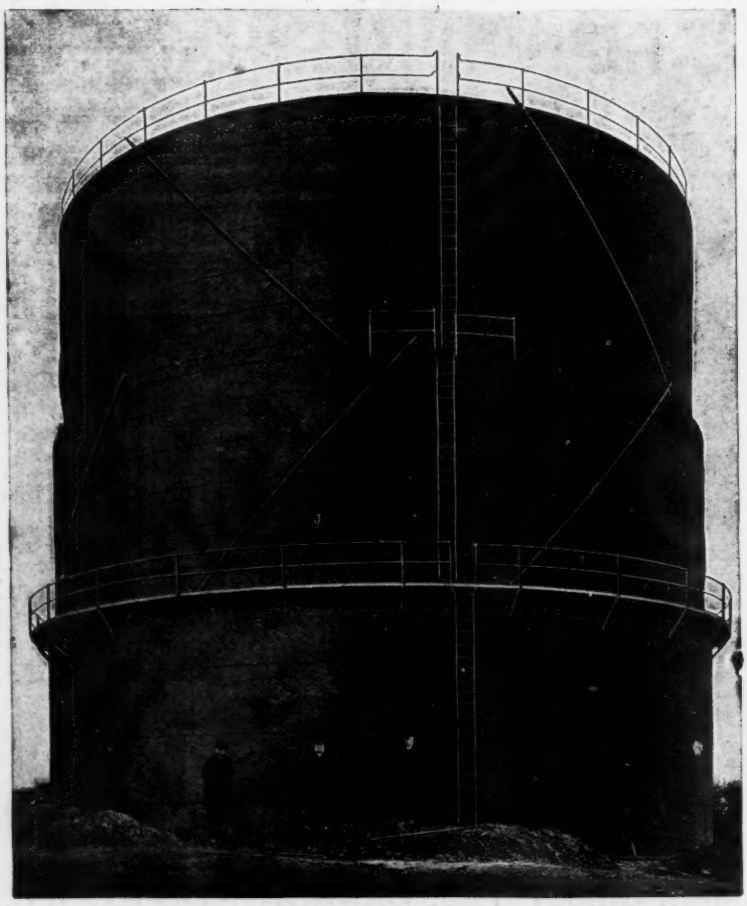

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SPIRAL-GUIDED HOLDERS
A SPECIALITY.

Original Makers.

Two-Lift Spiral-Guided Gasholder and Steel Tank (Clayton's Patent) Made and Erected for the Northallerton Consumers' Gas Company, Ltd.

CAPACITY 110,000 cubic feet.

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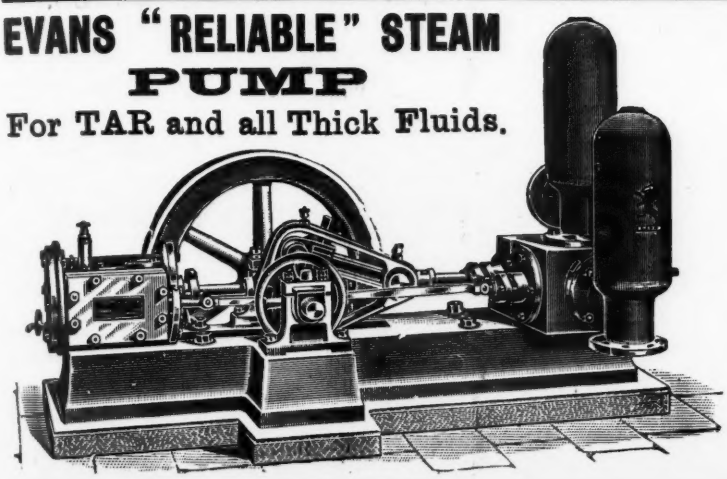
For TAR and all Thick Fluids.



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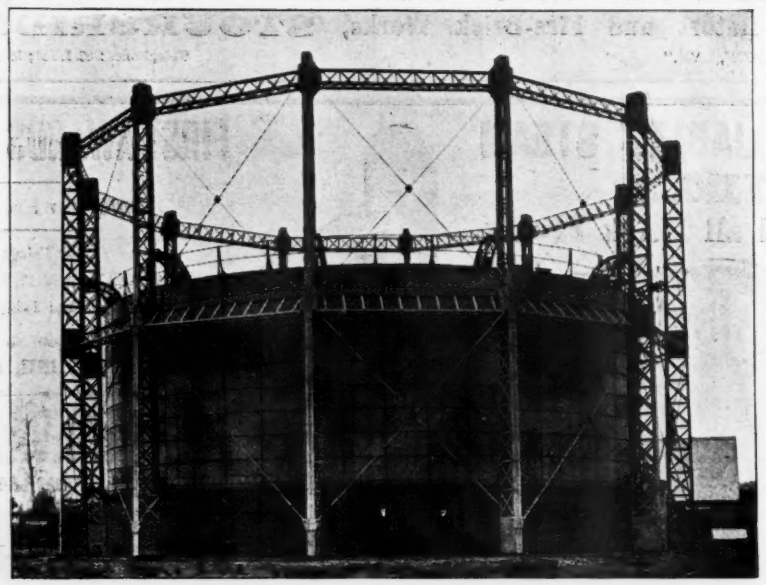

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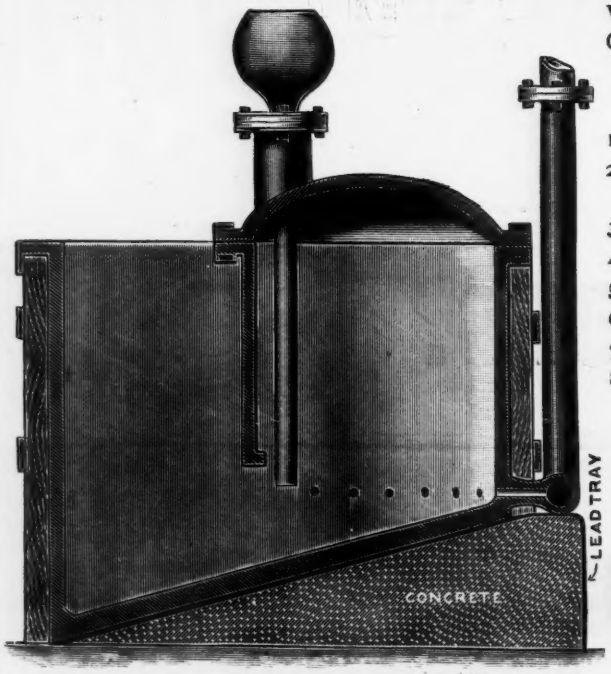
SULPHATE OF AMMONIA PLANT



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Williams' and Fenner's Patent Saturator with Outside Cracker Pipe, having the following

ADVANTAGES:—

1. Equal distribution of Steam and Ammonia.
2. Perfect agitation and boiling of the Acid Liquor.
3. No possibility of local Alkalinity.
4. Consequently no formation of Blue Salt.
5. Sulphate is easily forced to point of discharge.
6. No incrustation.
7. No renewals of Cracker Pipe.
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